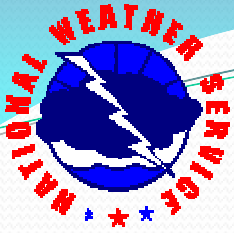




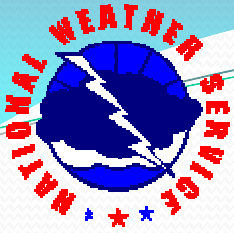
Tsunami: The Threat to the Gulf of Mexico

John Metz - National Weather Service – Corpus Christi, TX



Fact

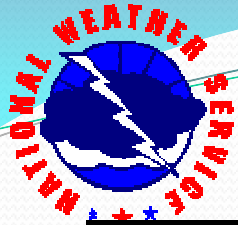
- NWS puts out millions of weather and water predictions every year.
- Very few Tsunami Watches and Warnings ever issued (none in Gulf/Atlantic).
- There have been less than a dozen scientifically legitimate earthquake predictions.* **Pielke 2000*



So What's the Probability?

- ***Probability***: A measure of how likely it is that some event will occur (1.0 = certain and 0.0 = never).
A Statistical Prediction.

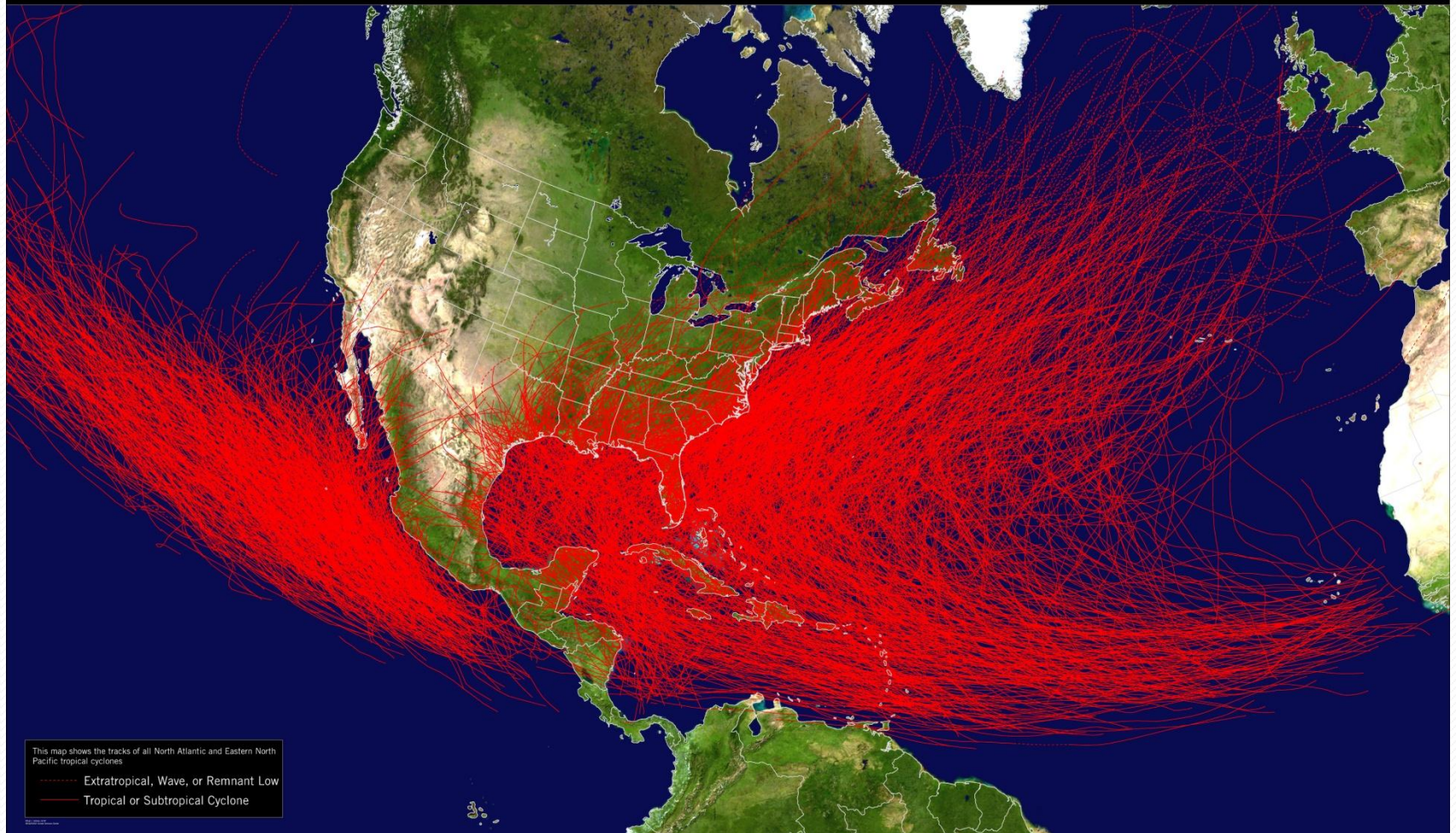
It's not ZERO!

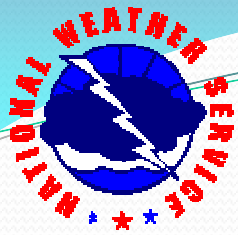


Effective use of probabilities requires data

Tropical Cyclone History

Data since 1949 in the Pacific, 1851 in the Atlantic



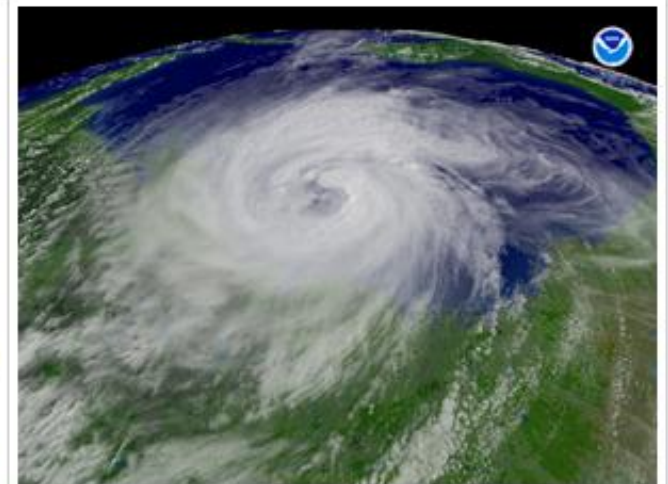


NOAA Expects Busy Atlantic Hurricane Season

May 27, 2010

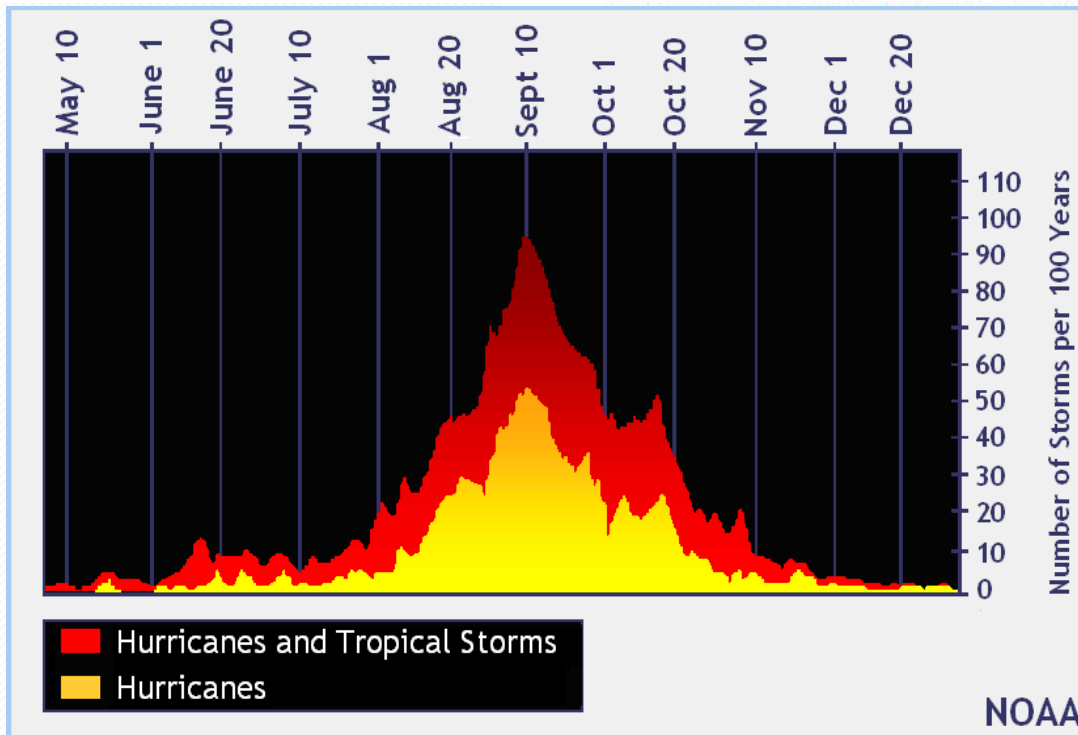
An "active to extremely active" hurricane season is expected for the Atlantic Basin this year according to the [seasonal outlook](#) issued today by [NOAA's Climate Prediction Center](#) – a division of the [National Weather Service](#). As with every hurricane season, this outlook underscores the importance of having a hurricane preparedness plan in place.

Across the entire Atlantic Basin for the six-month season, which begins June 1, NOAA is projecting a 70 percent probability of the following ranges:

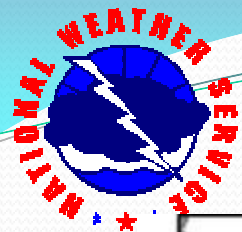


Hurricane Ike, 2008.

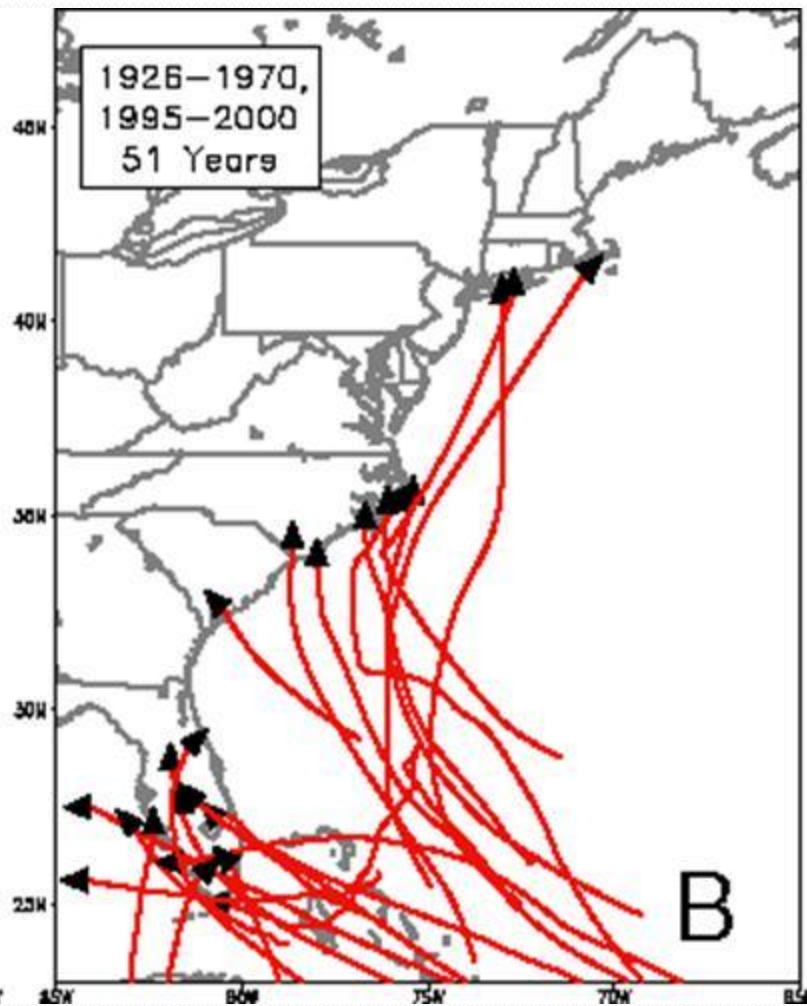
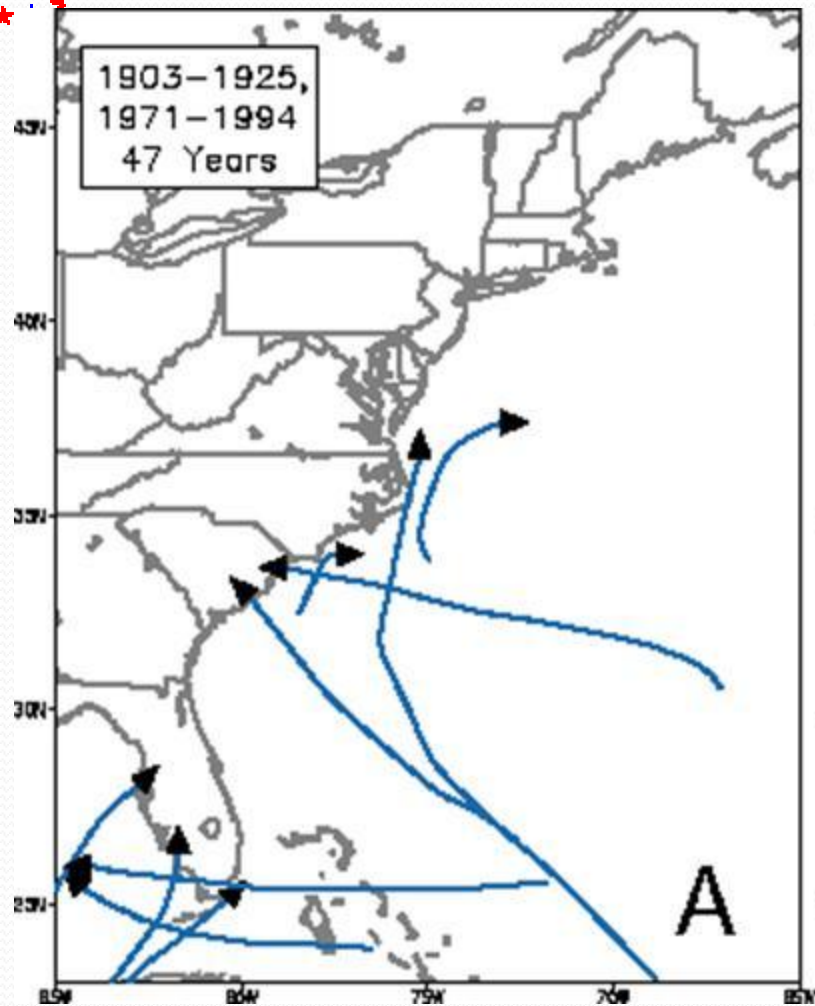
[High resolution](#) (Credit: NOAA)



**Tropical Cyclone Season
Forecasts Produced
Annually**

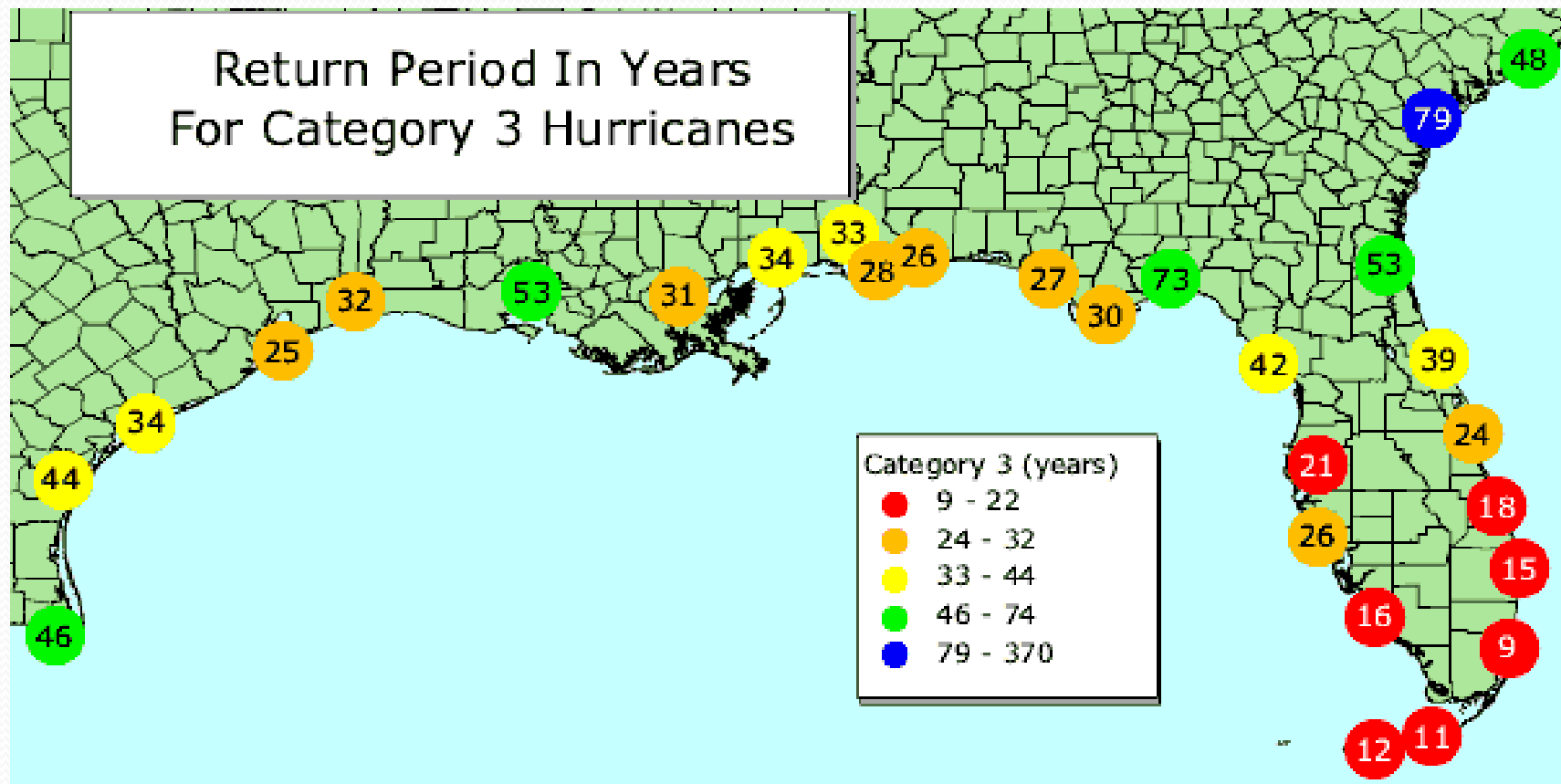


Multi-Decadal Hurricane Trends

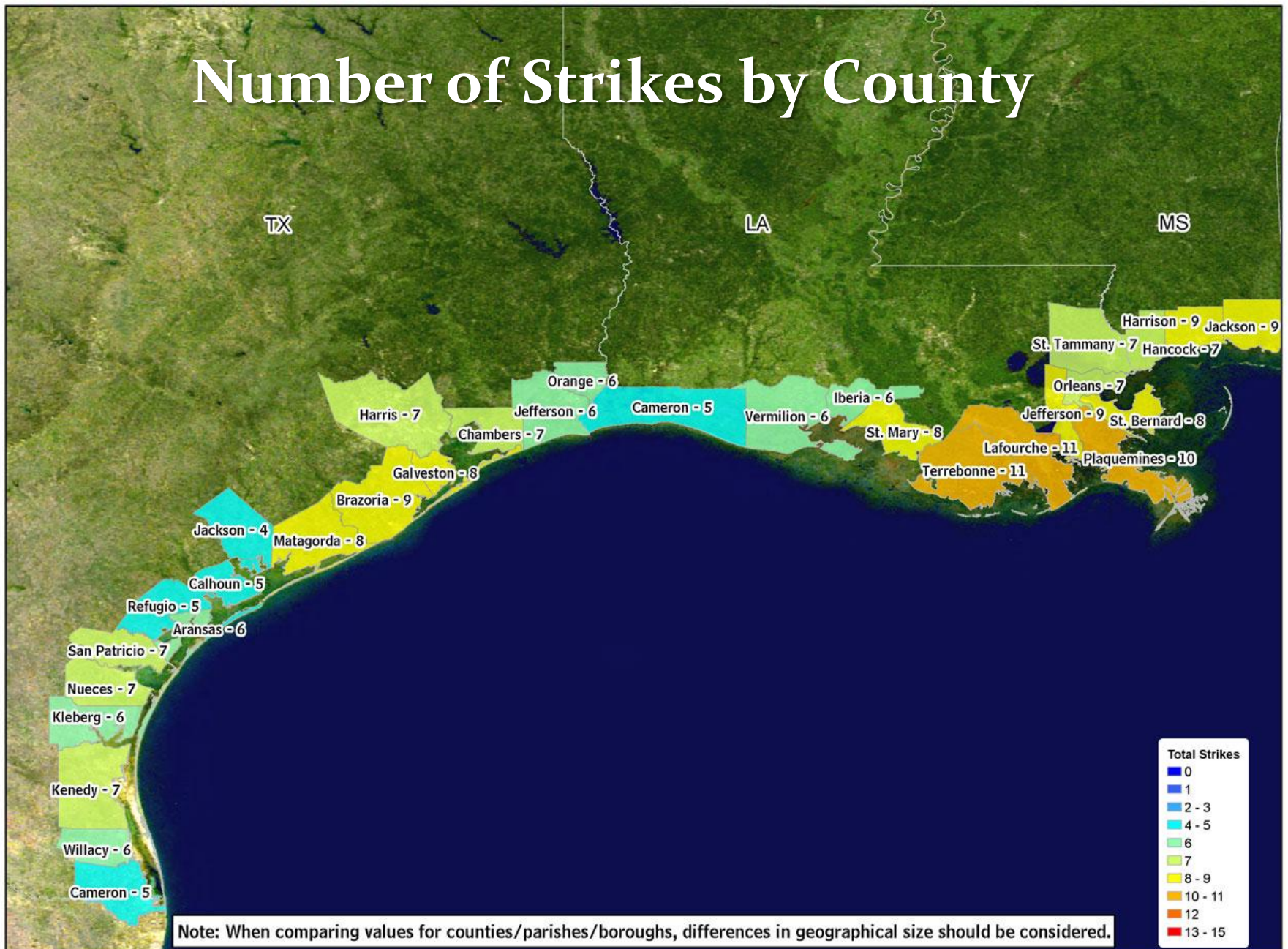




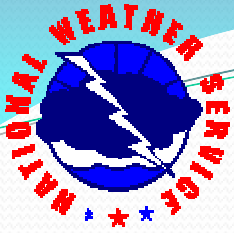
Return Periods Calculated



Number of Strikes by County



Total number of major hurricane strikes by counties/parishes/boroughs, 1900-2009



There is Nothing Like this
Rich Data Set and Experience Base for
Tsunamis in the Gulf or Atlantic!

*But there is enough data to identify a need
for tsunami preparedness measures in Texas*



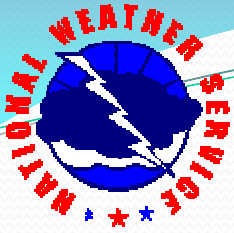
Tsunami Overview

Tsunami 101

Tsunami Dangers & Coastal Destruction

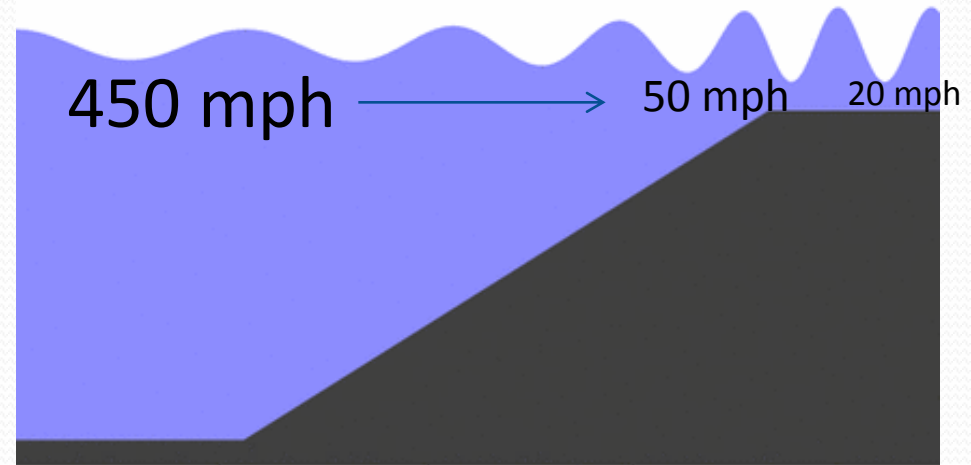
Threats to U.S. East / Gulf Coasts

Tsunami Warnings & Tsunami Warning Network



What is a Tsunami ?

- Japanese Word Tsunami : Harbor Wave
- Series of Long Ocean Waves
- Strike Coast 5-40 Minutes Apart
- 1st Wave not Always Largest
- Coastal Waves reach 15-30 ft in Height (100' in Larger Tsunami's)
- Water can Penetrate Several Miles Inland

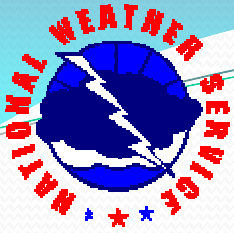


As it enters shallow water, the tsunami wave slows down and height increases



Tsunami Approaching Japan



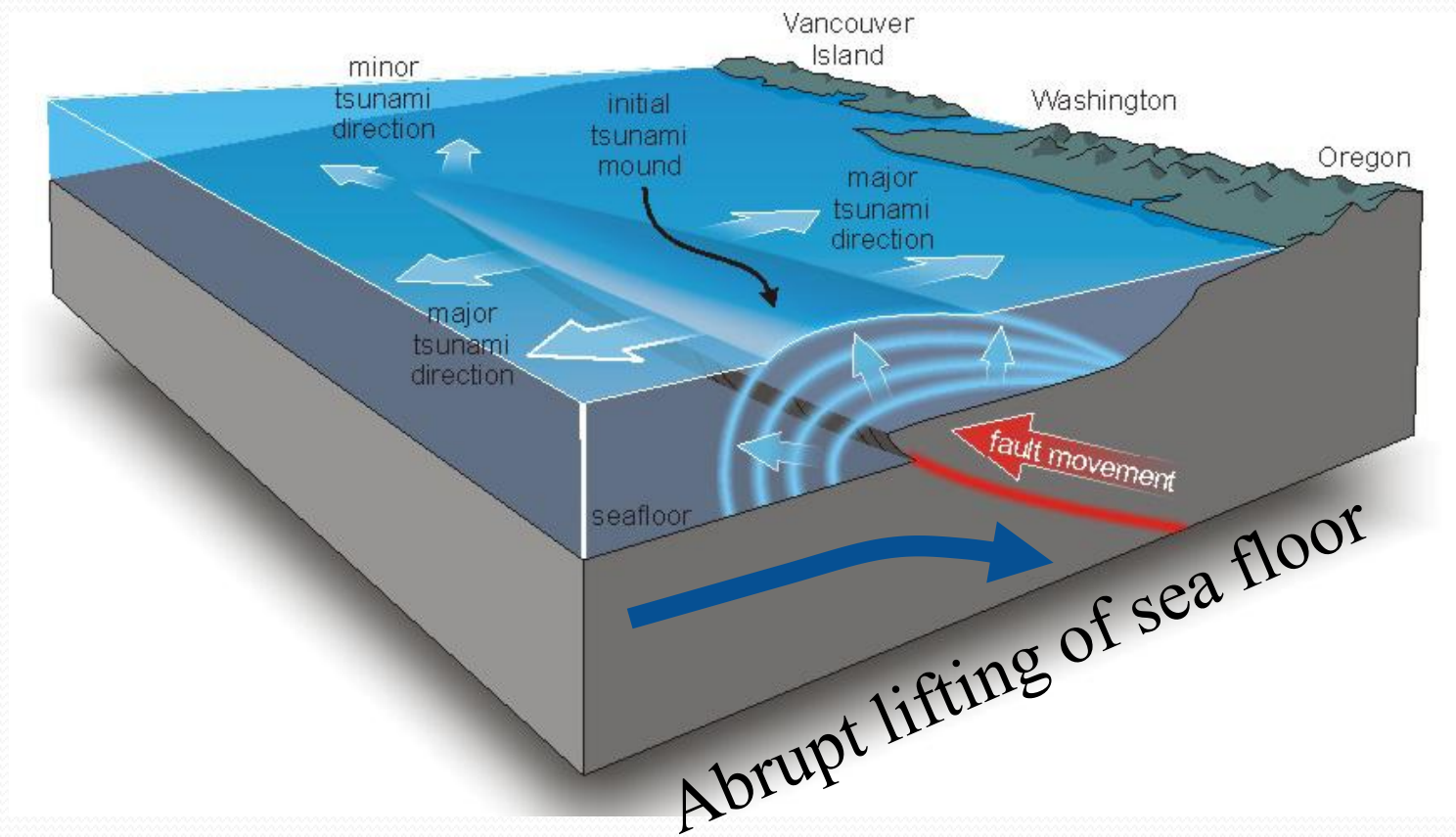


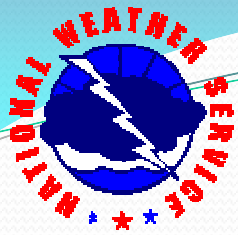
How Tsunamis are Generated

- Underwater **Earthquake**
- Underwater **Landslide**
- Underwater **Volcanic Eruption**
- **Asteroid** Impact



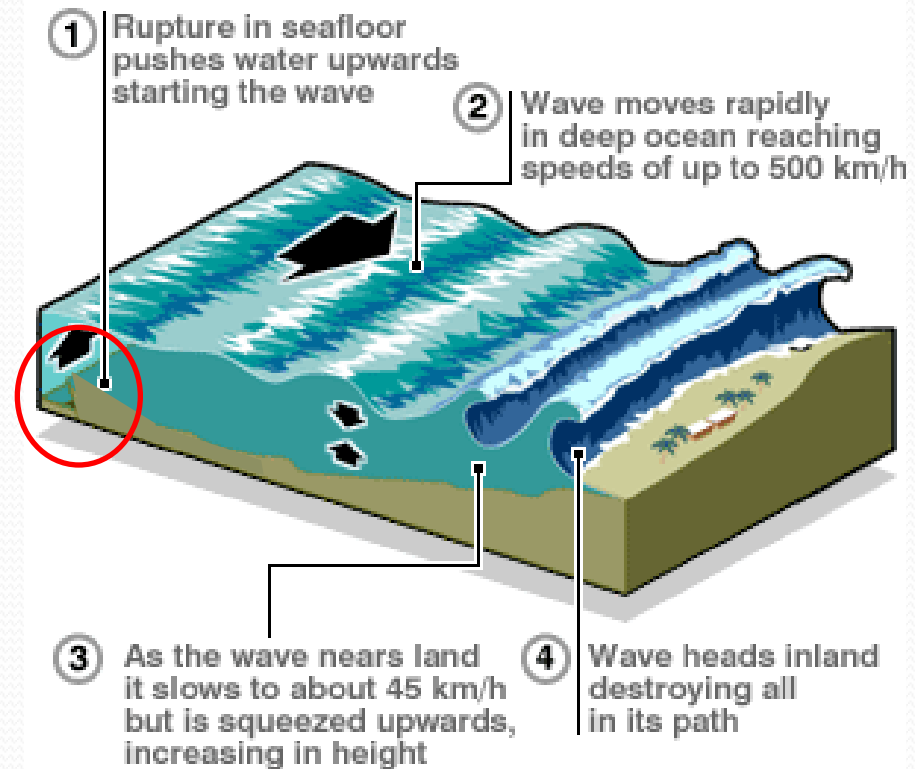
Underwater Earthquake

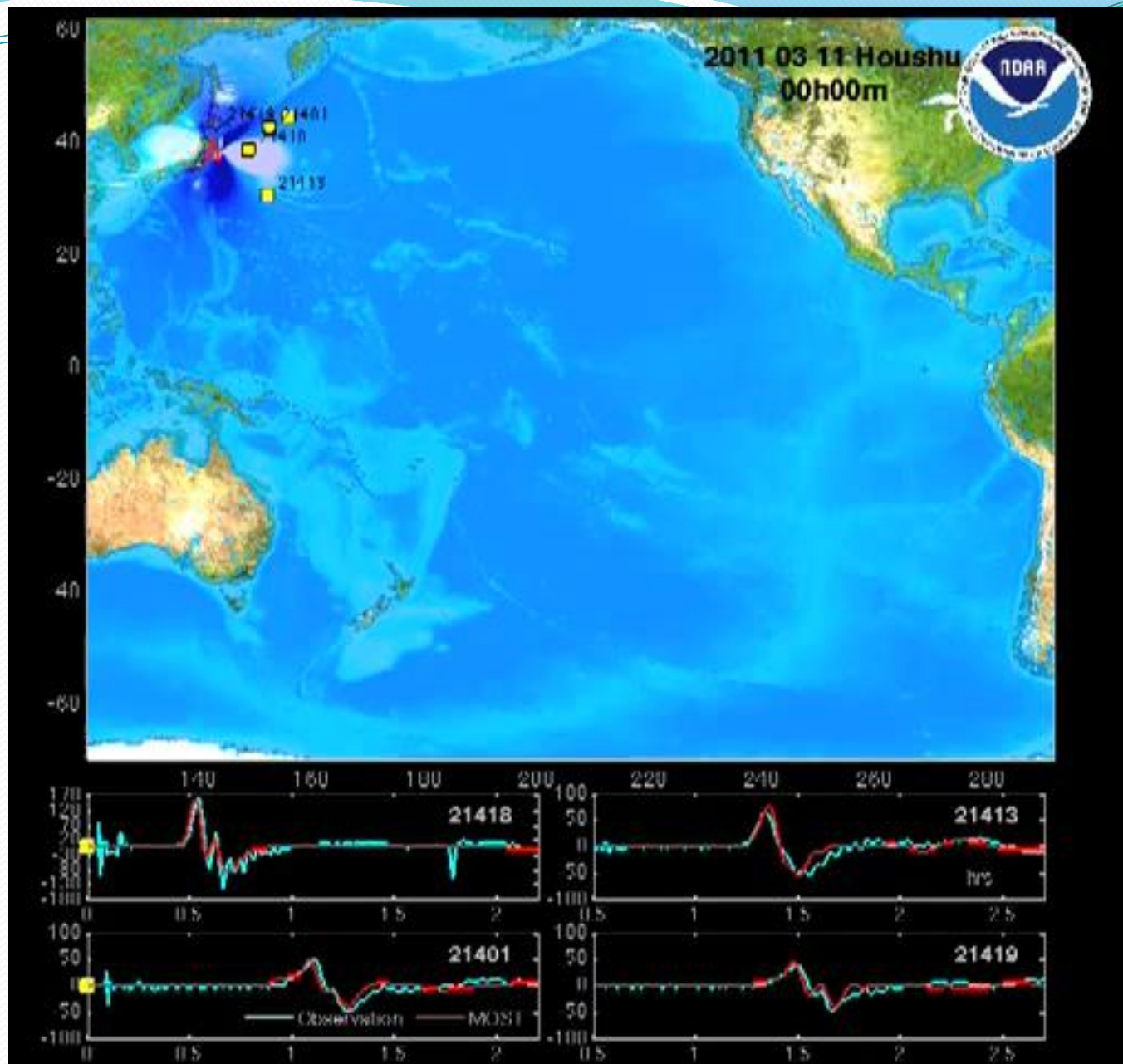


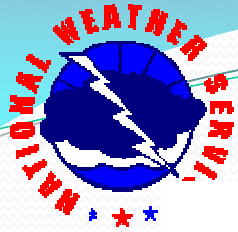


Tsunami Formation

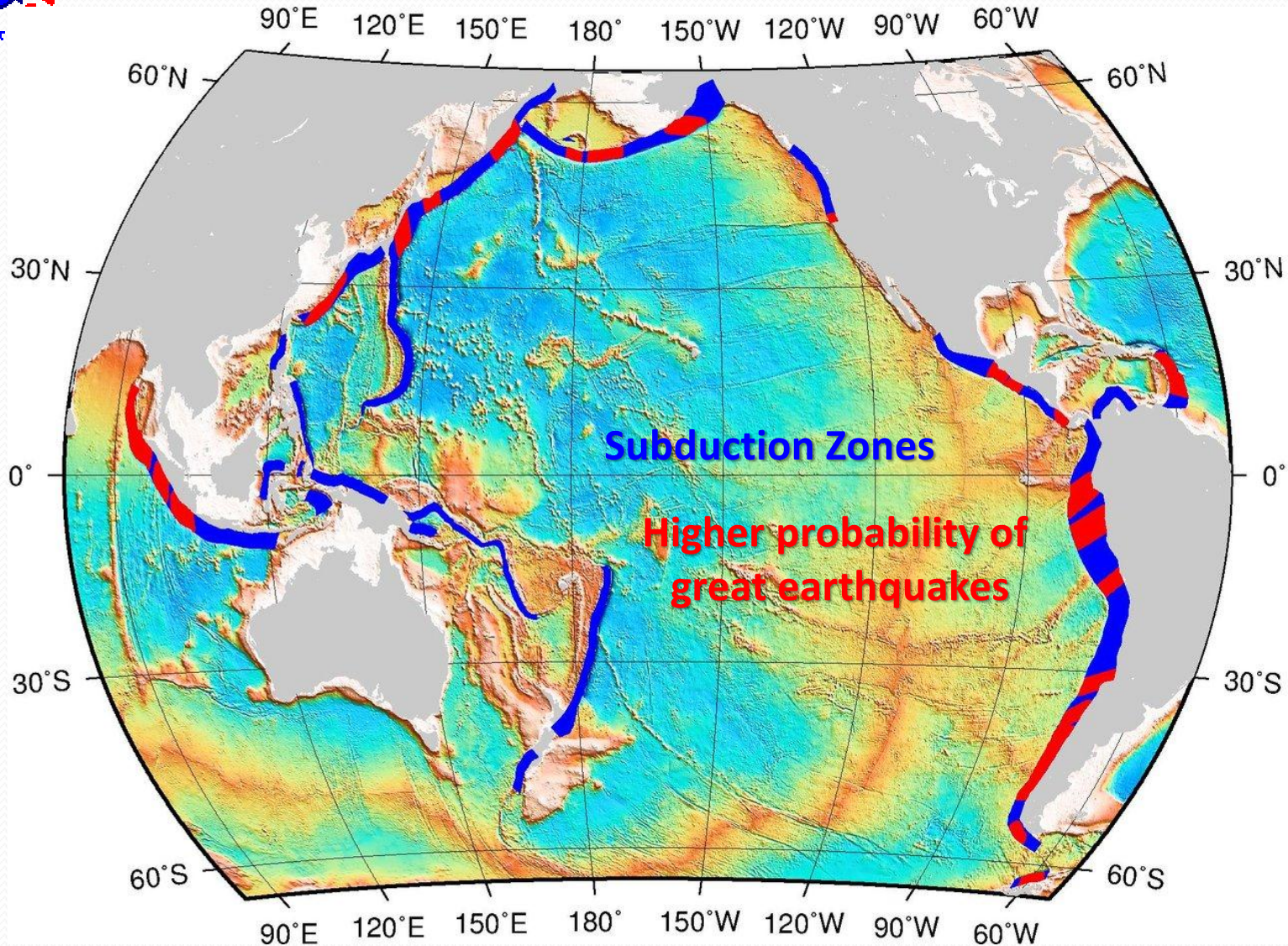
- Sub-Oceanic Earthquakes
 - Subduction zones can cause Megathrust Earthquakes
 - Shallow
 - Typically Need 7.0 or Greater Earthquake
 - 83% occur in Pacific Ocean

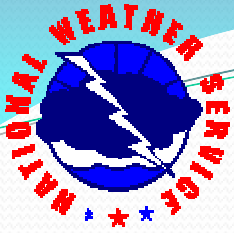






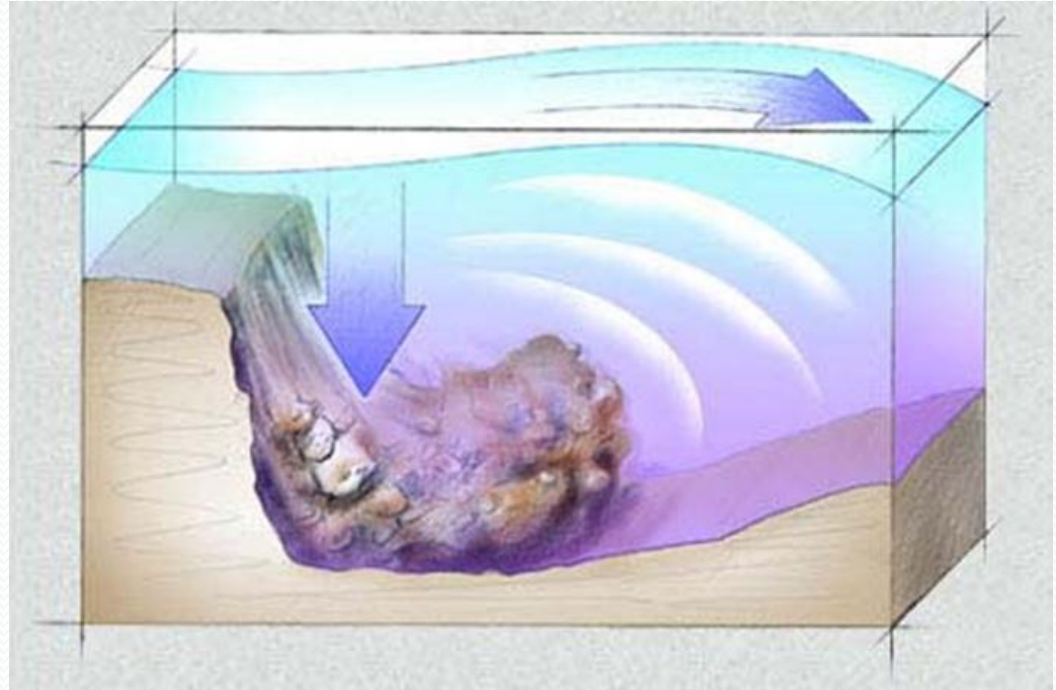
Mega Quake Hotspots

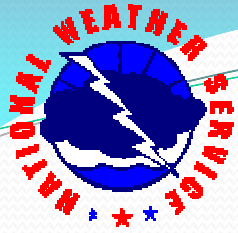




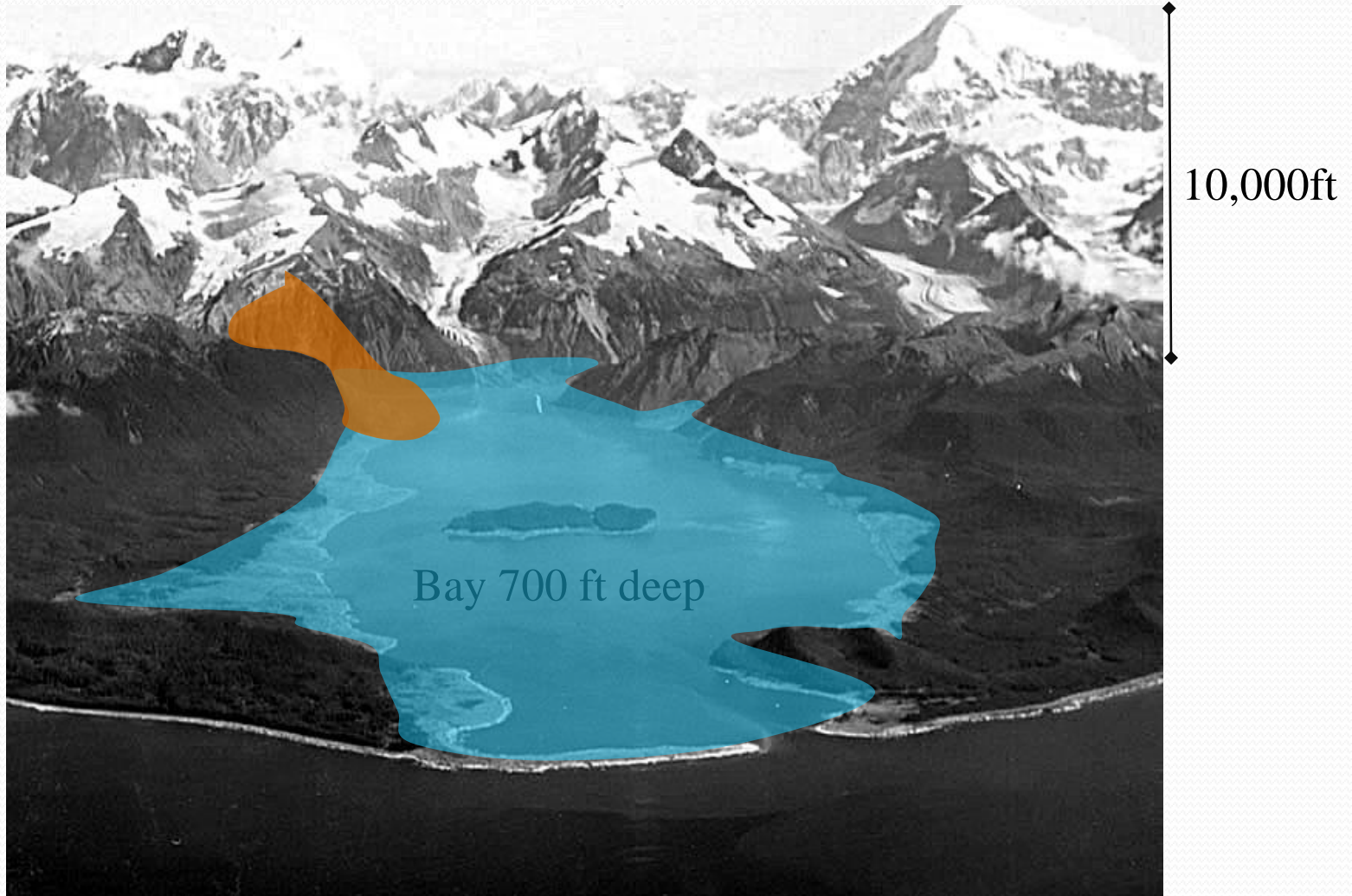
Underwater Landslide

- Second Most Common Cause of Tsunami
- Underwater or above Water into Sea
- Displacement or Slump of Sediment Displaces Water & Generates Tsunami





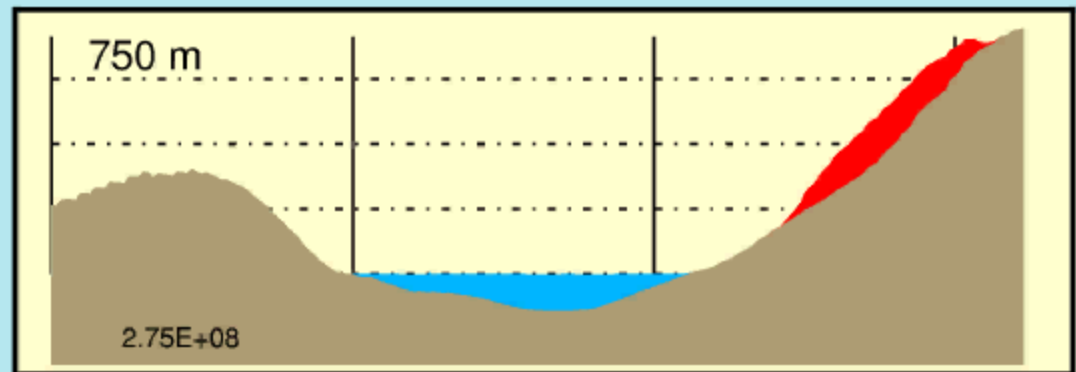
Lituya Bay Landslide Alaska



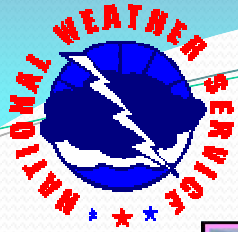
July 9, 1958, Earthquake caused Landslide and 1,720 ft Mega Tsunami

00:00:00

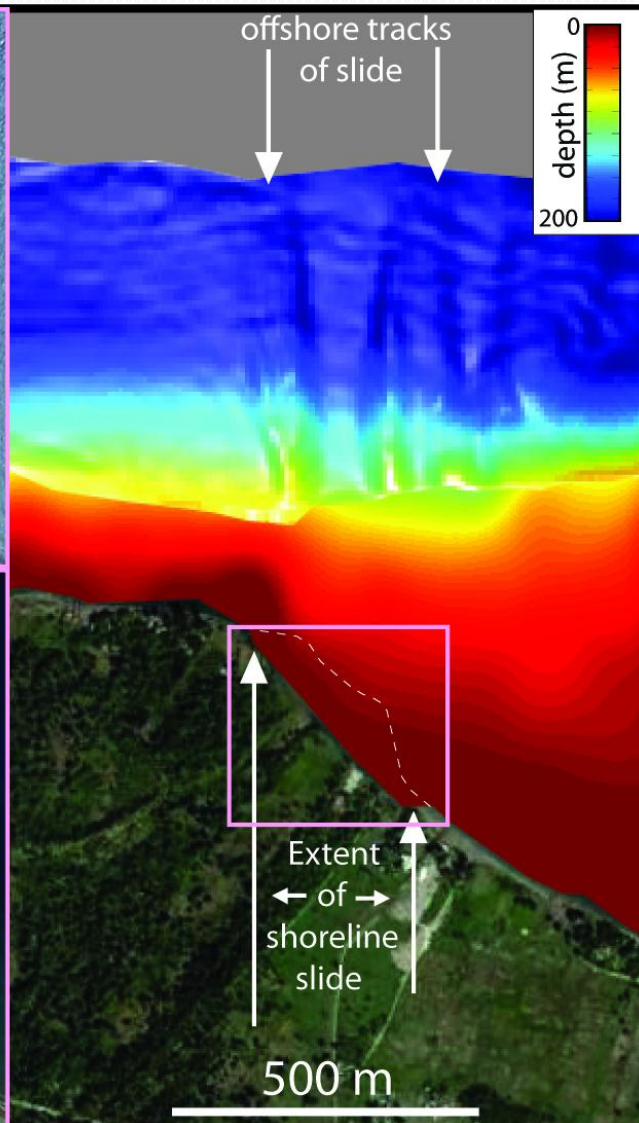
.0 m/s 1.4E-02 J
0.0E-01 J 1.4E-02 J
0.0E-01 J 0.0E-01 J
0 1 2km

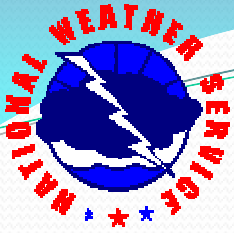


1958 Lituya Bay Landslide Tsunami Simulation



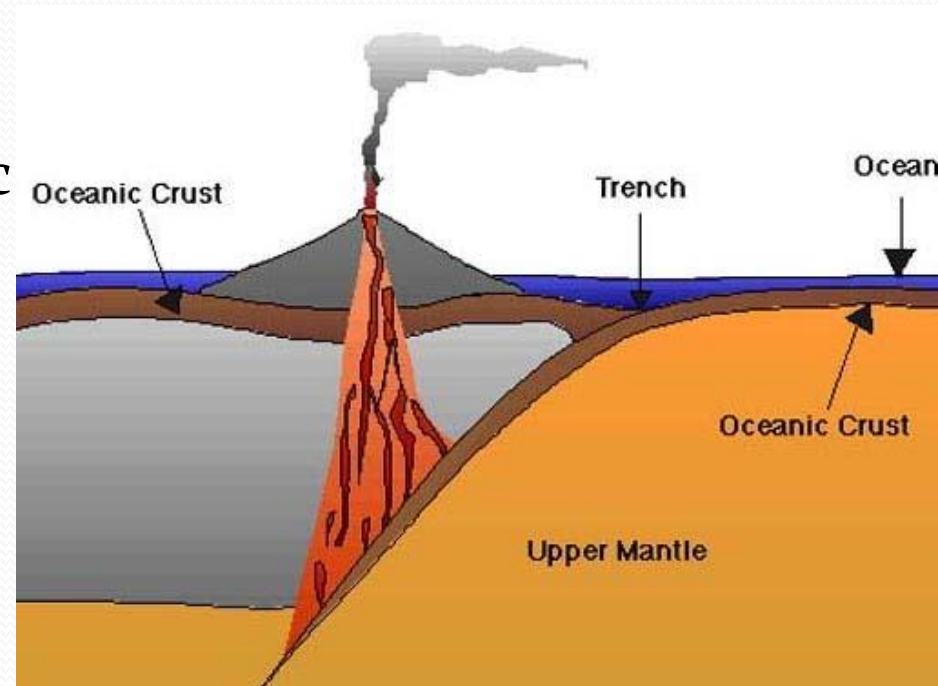
Haitian Earthquake/Landslide

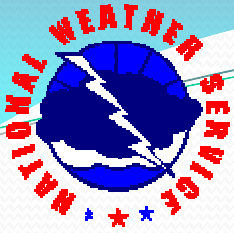




Volcanic Generated Tsunami

- Collapse of Lava Dome Preceding Eruptions
- Volcanic Flank Failure (Volcanic Explosion Collapses Side of Volcano Triggering Wave)
- Lava Eruption Quickly Displacing Water
- Energy Dissipates Faster Than Earthquake Generated Waves; Weaker Tsunami

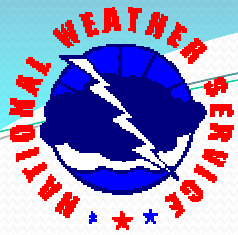




Asteroid Impact Generated Tsunami

- Cosmic Object Strikes Ocean
- Displaces Huge Amounts of Ocean Water
- Momentum From Falling Debris Transferred to Water Generating Tsunami




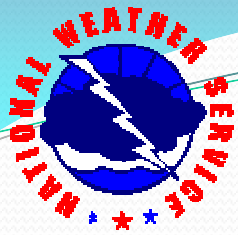


Frequency of Asteroid Impacts



Arizona – 50,000 yrs old

- 3 mile diameter impacts occur every 10 million years
 - ½ mile diameter impacts occur every 500,000 years
 - 150 ft diameter impacts occur every 1,000 years
 - 33ft diameter impacts occur every year (energy of atom bomb, but explode in upper atmosphere)
 - 500 meteorites (<33ft) reach earths surface every year.
- 

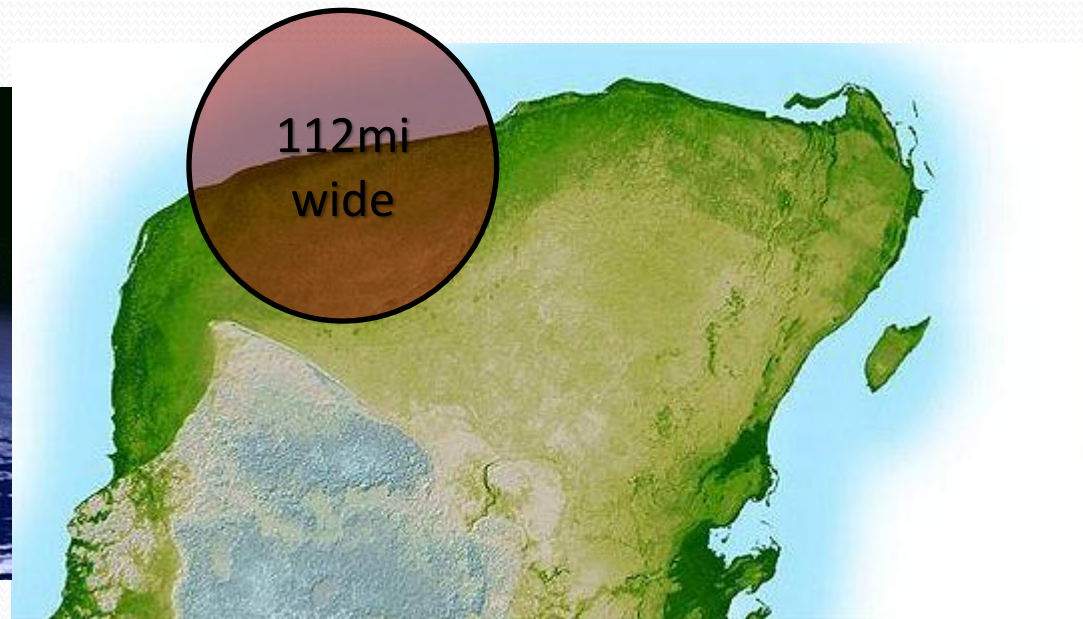


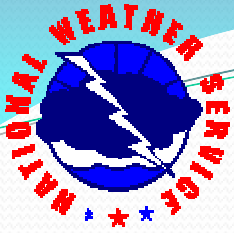
Frequency of Asteroid Impacts

- Last 6+ mile diameter strike to earth was 65 million years ago. (Cretaceous extinction)
- Future? At least one known asteroid $>1/2$ mile diameter is on course to impact earth on March 16, 2880.



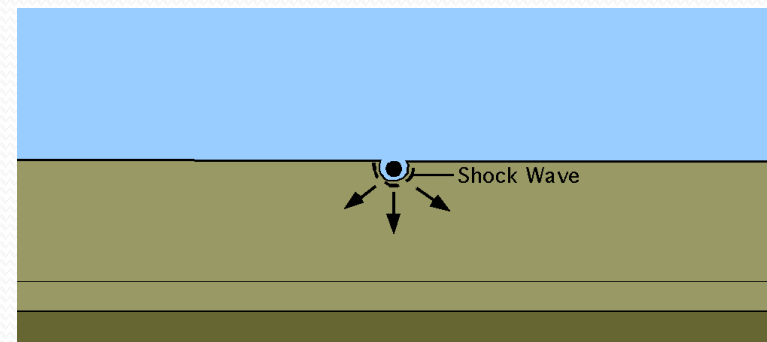
1.9 mile high tsunami

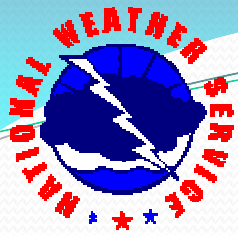




Chicxulub Crater - Yucatan

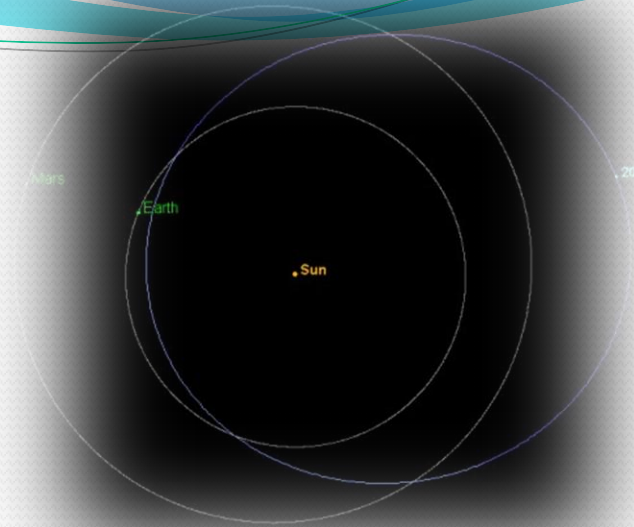
- Discovered during oil exploration in 1970's
- 6–9 mi asteroid struck Chicxulub on Mexico's Yucatan Peninsula.
- The collision released a billion times more energy than all the bombs dropped on Nagasaki and Hiroshima.
- The impact would have caused some of the largest **mega tsunamis** in Earth's history.
- Confirmed extinction of dinosaurs at end of cretaceous period.

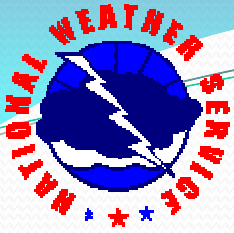




Future Impacts

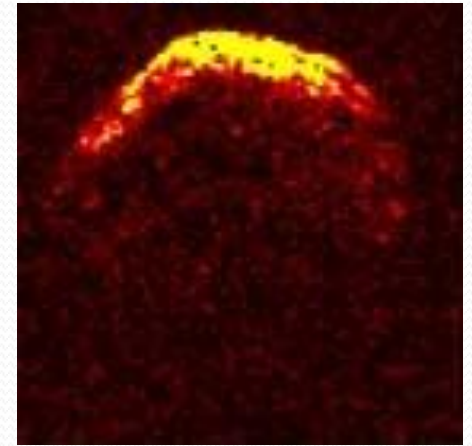
- Asteroid AG5 has a 1 in 625 chance of hitting Earth on Feb. 5, 2040.
- It's one of 8,744 near-Earth objects NEOs discovered as of March 1, 2012.
- 1,305 of these NEOs have been classified as Potentially Hazardous Asteroids, (>500 ft) and close to earth.
- 15-30ft Tsunami would arrive 6 minutes after impact if you were 5mi away.

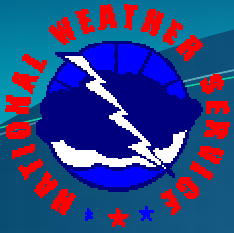




Collision Course?

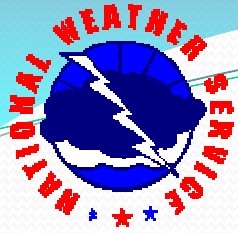
- If asteroid **1950 DA** continues on its present orbit, it will approach Earth on March 16, 2880, and has an impact probability of roughly 1 in 300.
- The energy released would cause major effects on the climate and biosphere which would be devastating to human civilization.





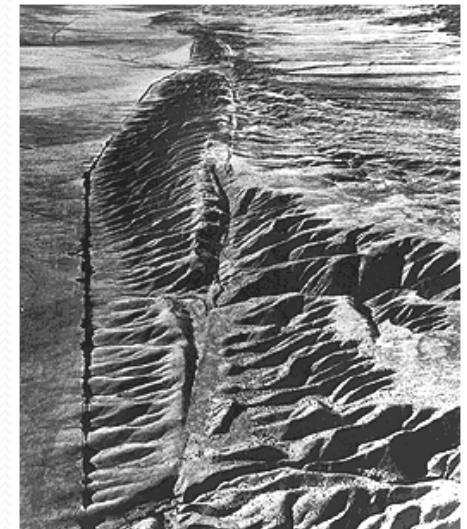
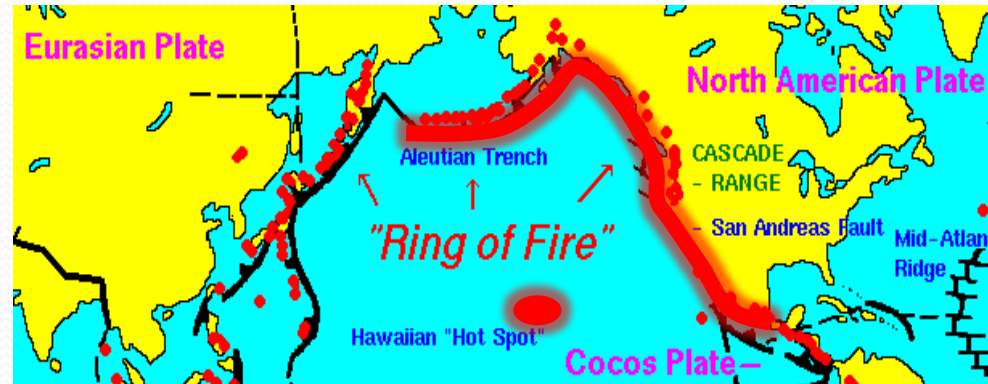
Tsunami Threat Areas

Pacific, Gulf and Atlantic

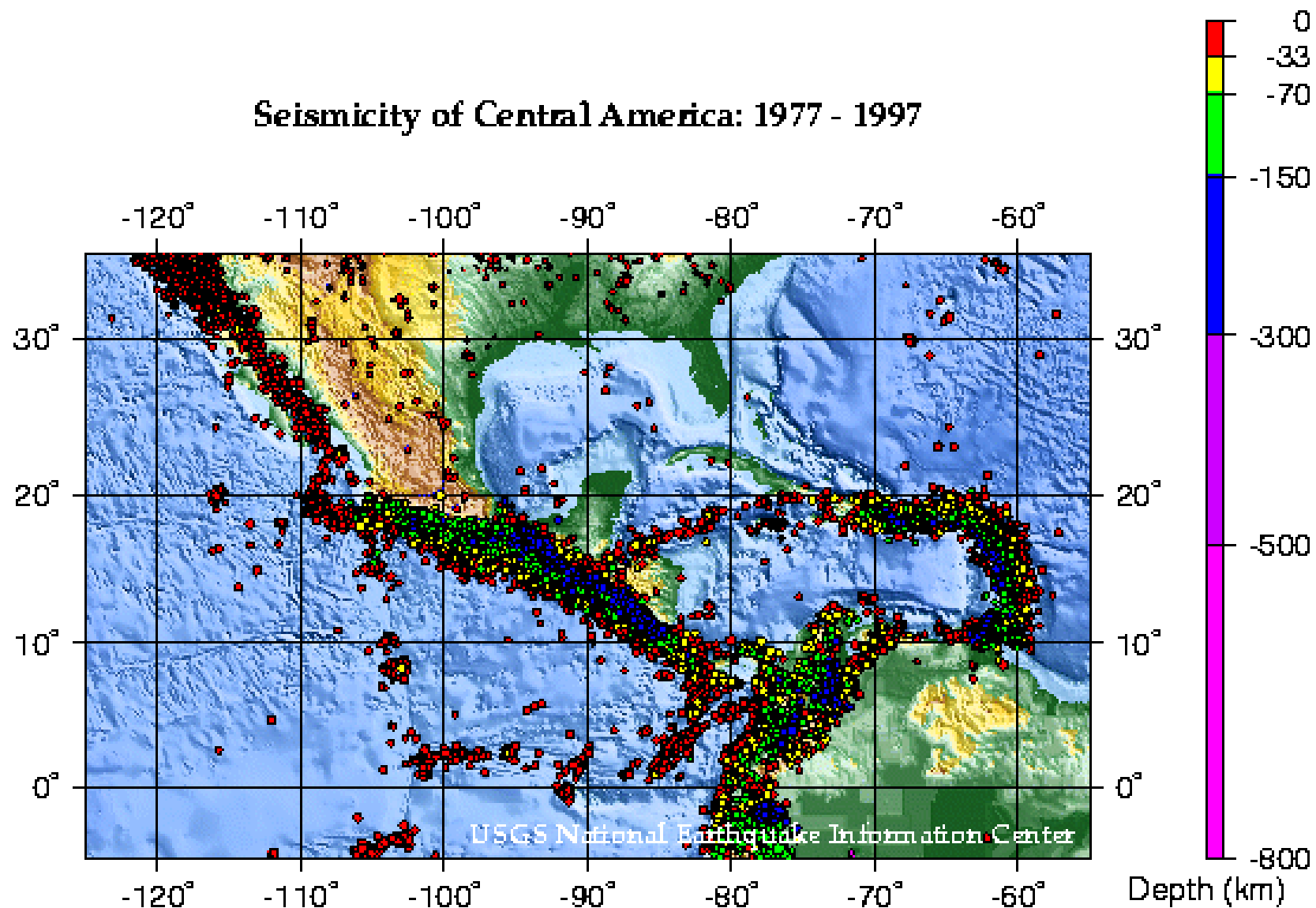


Greatest U.S. Tsunami Threat

- Greatest Threats: Coastal Alaska, Hawaii, & U.S. West Coast
- Occur near Active Tectonic Plate Boundaries
- Active Volcanic Region
- Ring of Fire

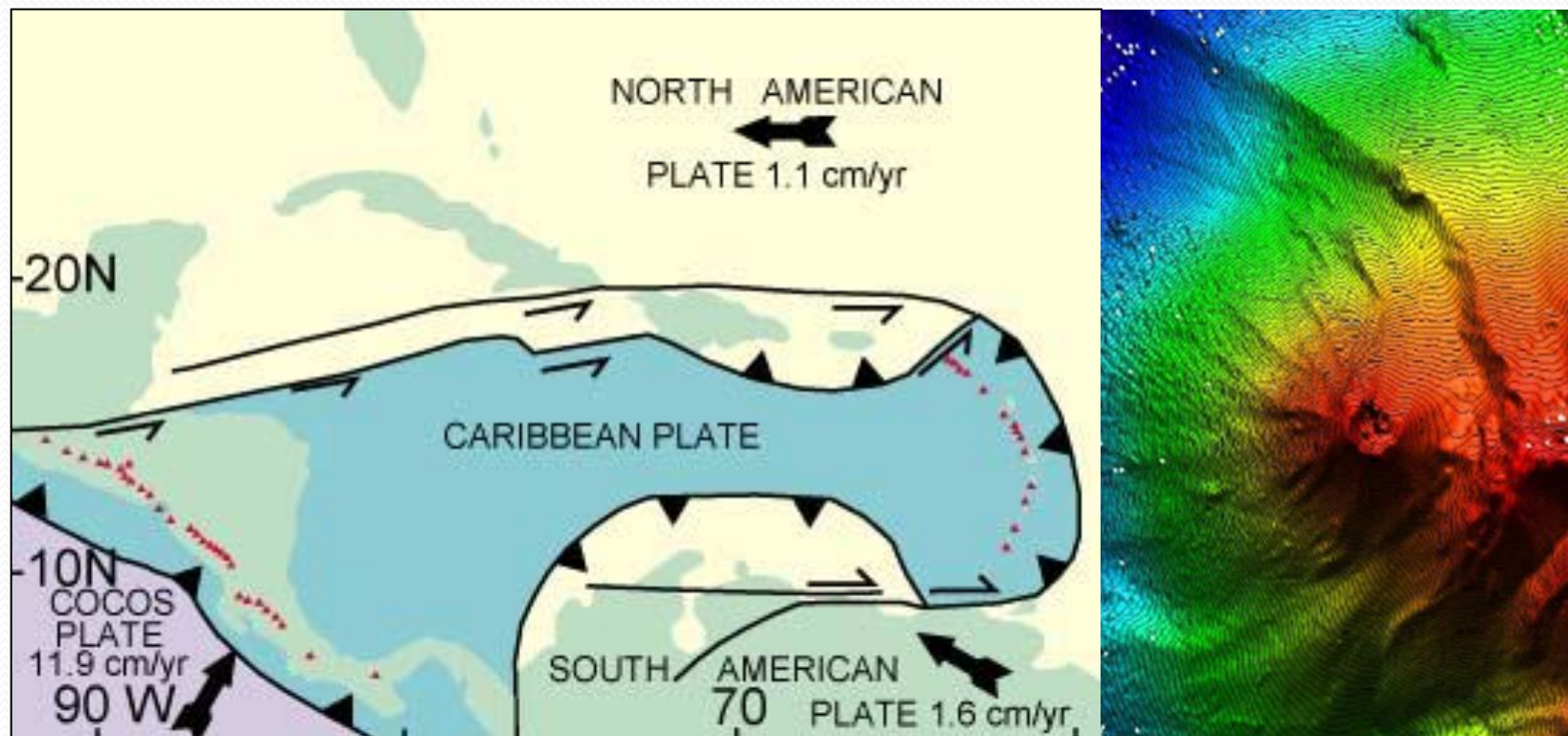


Seismicity of Central America: 1977 - 1997





Gulf & Caribbean Tsunami Threat



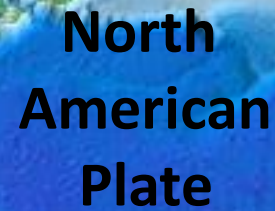
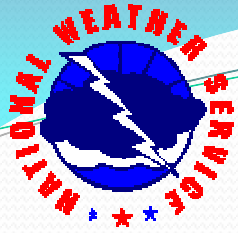


Figure 5-2: Perspective view of the tectonic elements in the Caribbean plate and seafloor topography.



Historical

Atlantic Tsunami Events

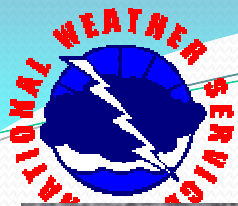


Caribbean Island Tsunami

3,000 Years ago



Devastating Tsunami

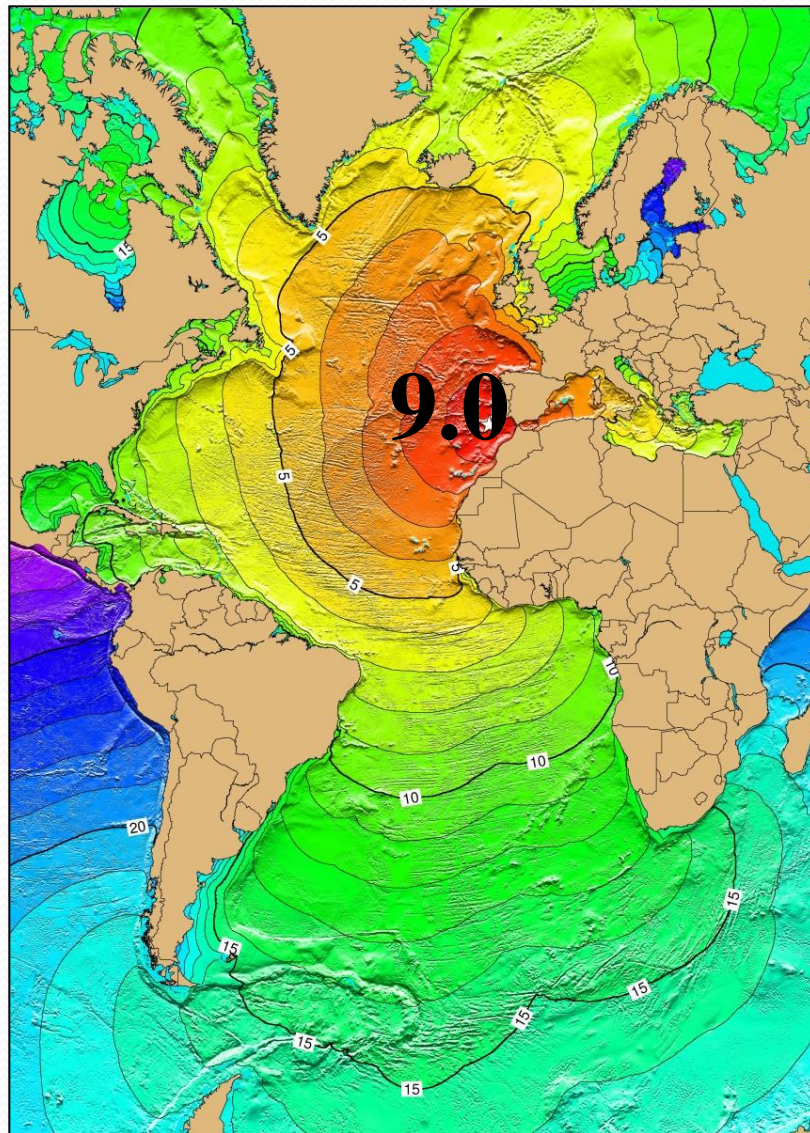
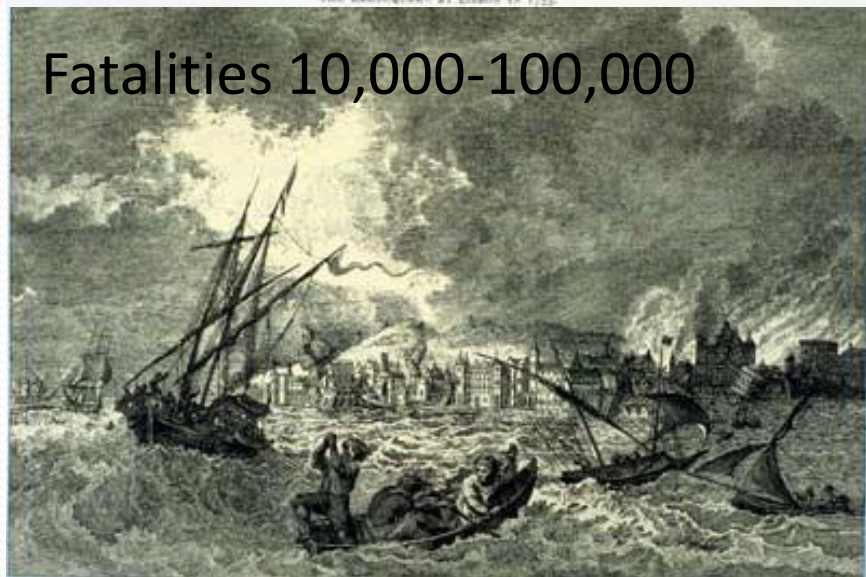


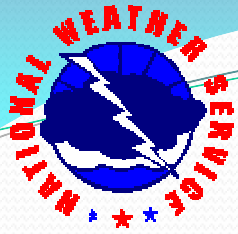
The Great Lisbon Quake of November 1st, 1755



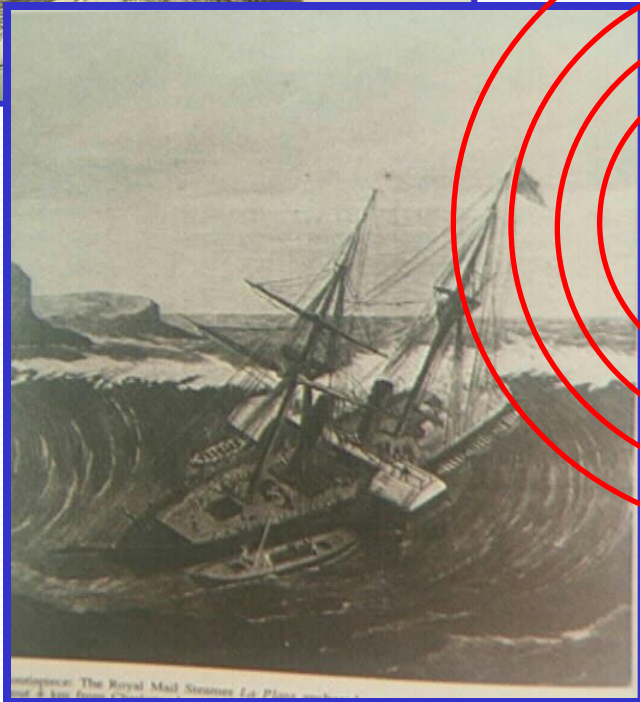
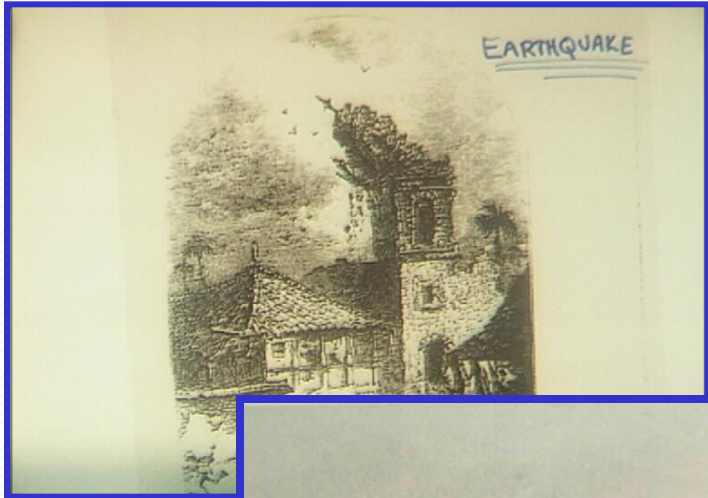
THE EARTHQUAKE AT LISBON IN 1755.

Fatalities 10,000-100,000

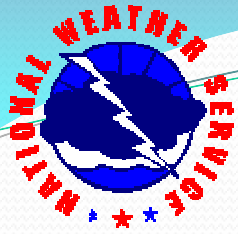




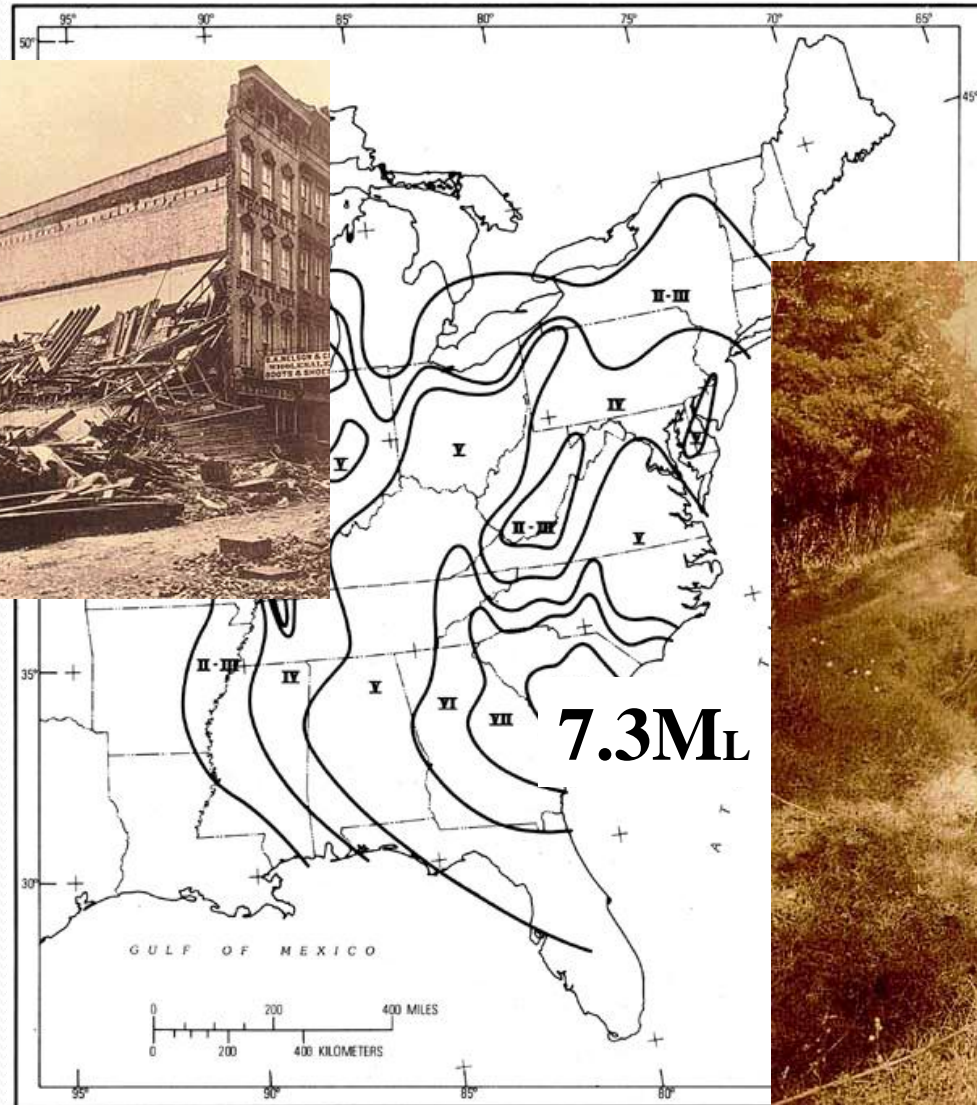
U.S. Virgin Islands Tsunami November 18, 1867



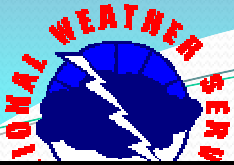
20-40ft Tsunami



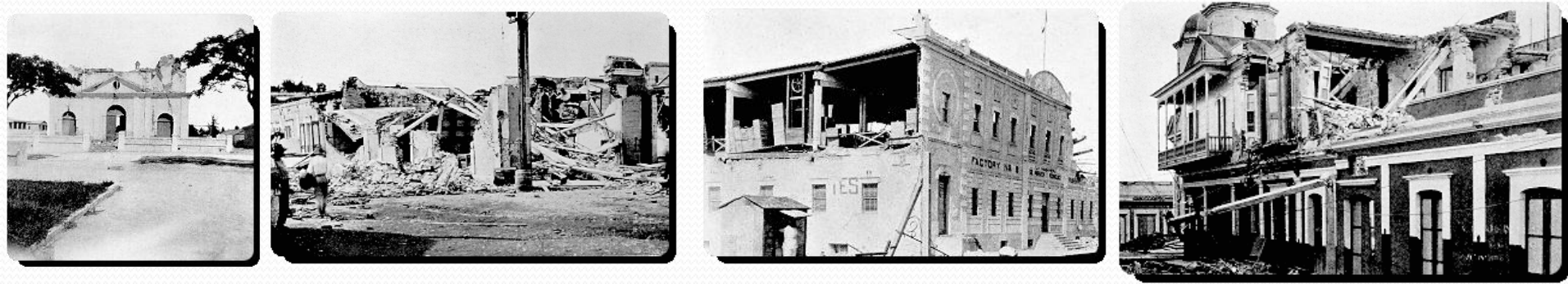
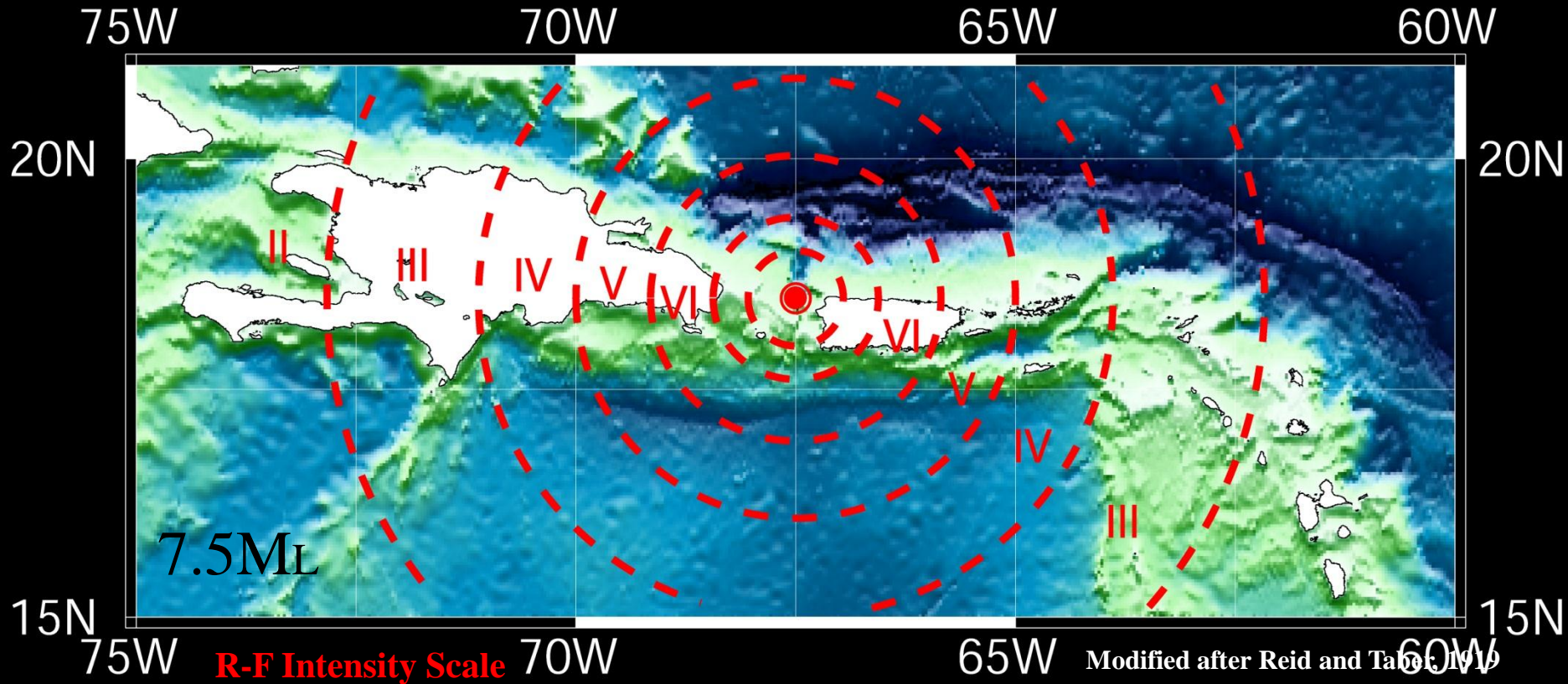
Great Charleston Earthquake August 31, 1886 9:50 p.m.

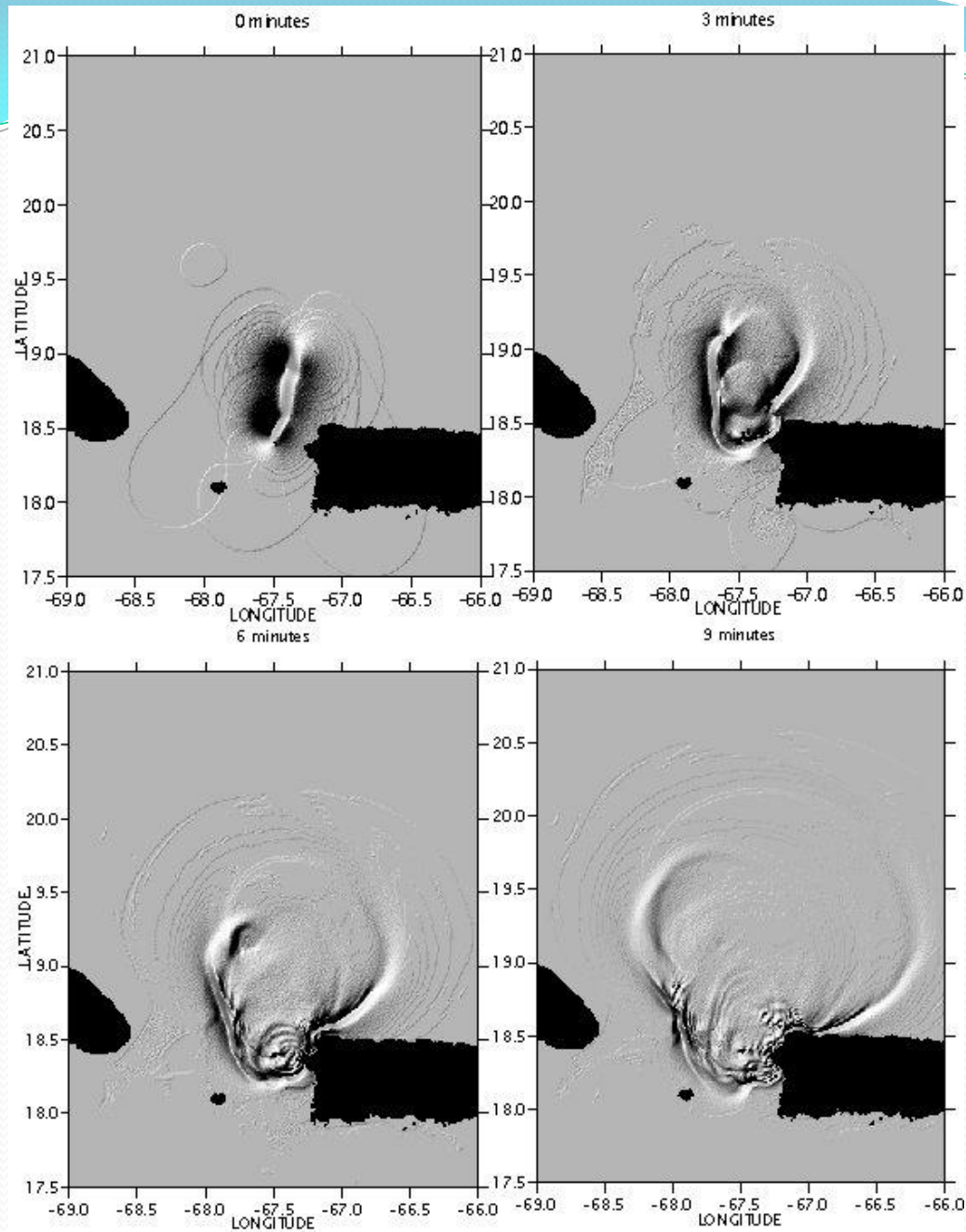


Fatalities 60

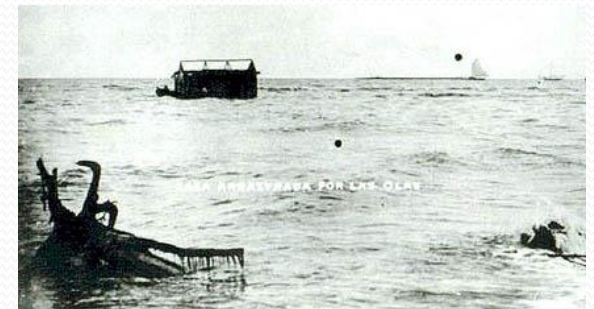


Puerto Rico Earthquake of October 11, 1918

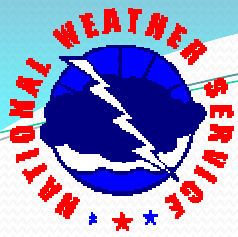




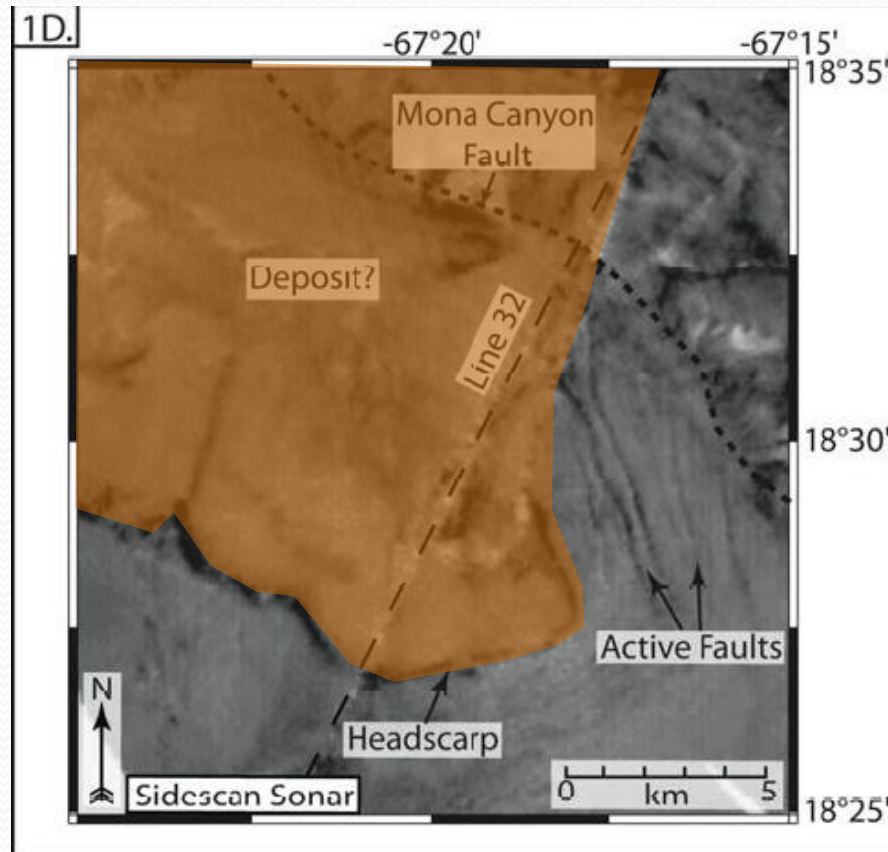
1918 Puerto Rico



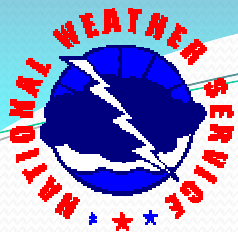
Tsunami Wave 15-18 ft
142 Fatalities



Earthquake & Landslide Generated Tsunami



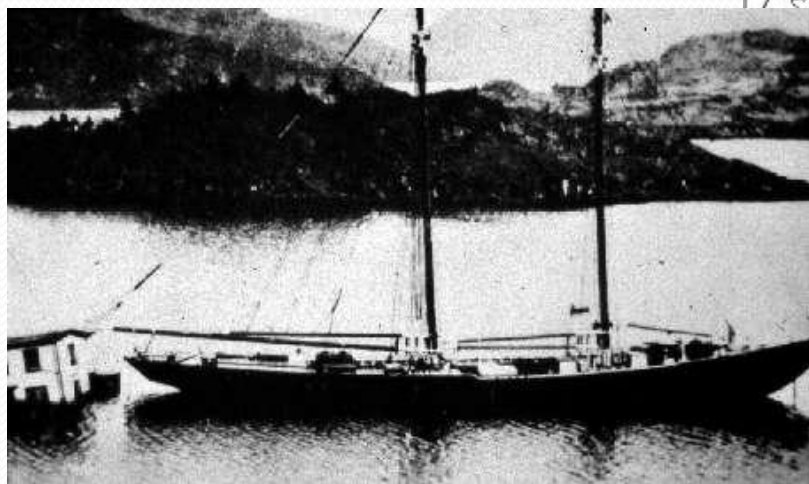
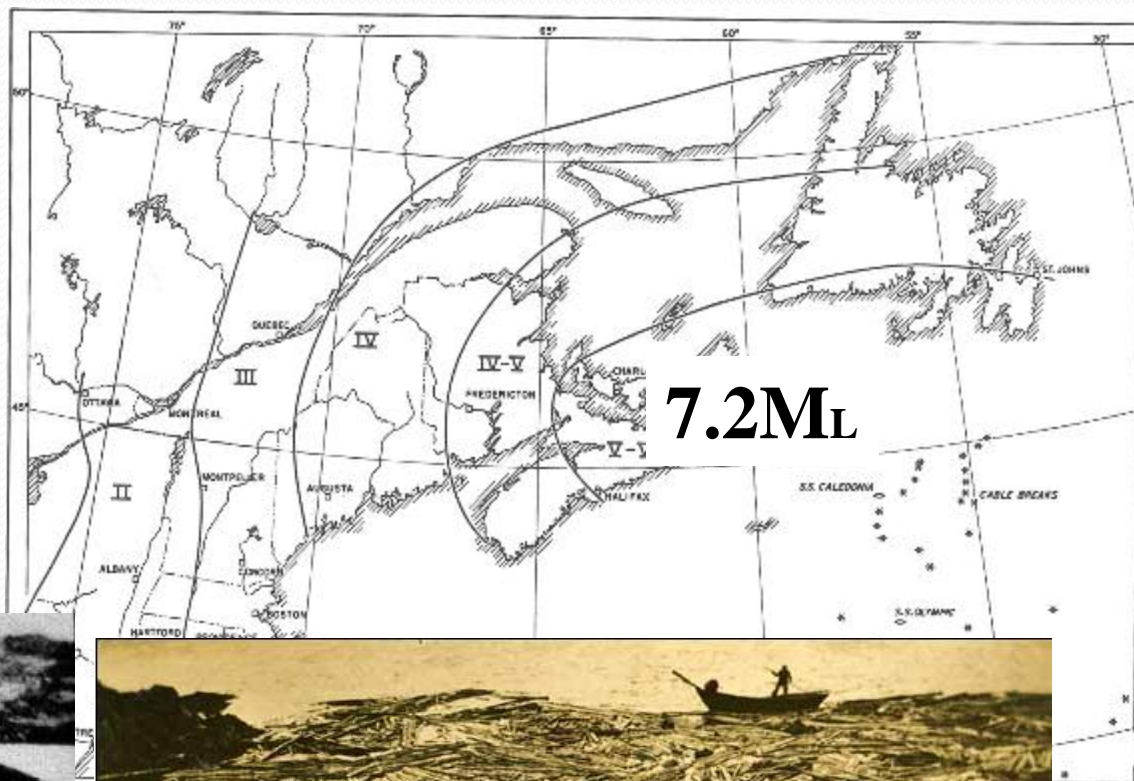
Puerto Rico 1918



Burin Peninsula, Newfoundland November 18, 1929

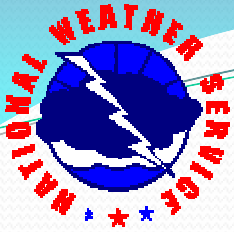
Earthquake & Landslide Tsunami

Fatalities 28



9-12 Ft





July 3, 1992 Daytona Beach Rogue Wave

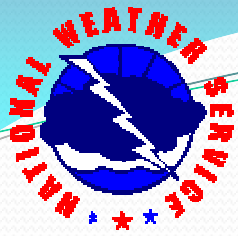
27 mile long rogue wave 18 feet high



Minutes after rogue wave hits Daytona Beach, boardwalk patrons survey the damage. Photo by Mike Orlando.

Experts theorize it was an underwater landslide and tsunami

200 vehicles damaged, 75 injuries

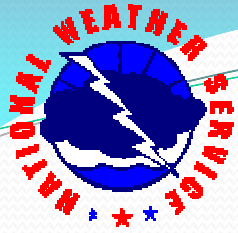


Underwater Landslide

Near African Coast



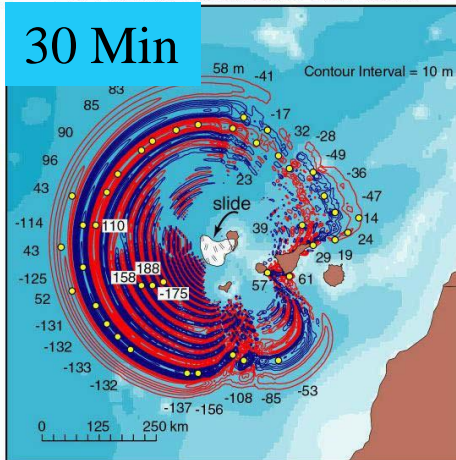
La Palma, Canary Islands



Model of La Palma Landslide and Mega Tsunami

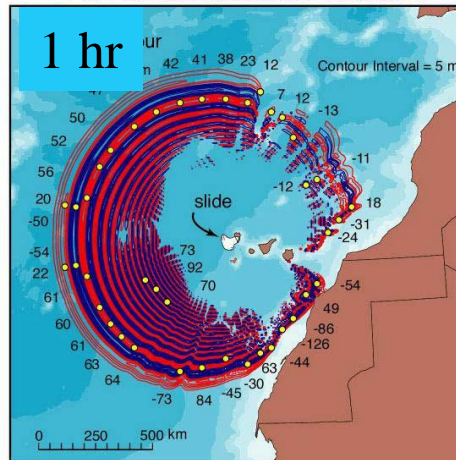
La Palma Landslide Tsunami

30 Min



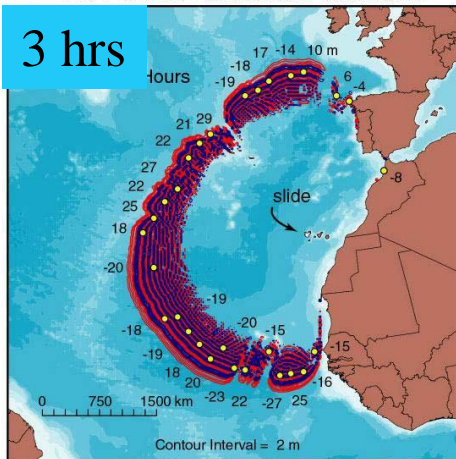
La Palma Landslide Tsunami

1 hr



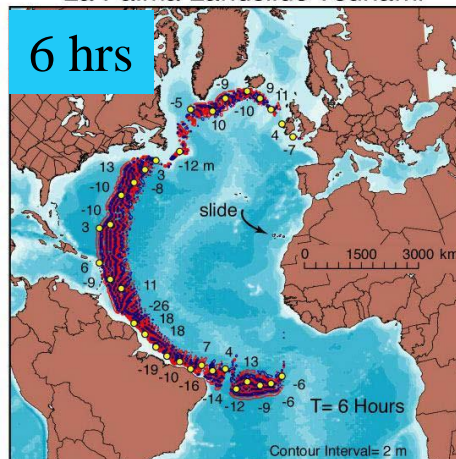
La Palma Landslide Tsunami

3 hrs



La Palma Landslide Tsunami

6 hrs



Ward and Day (2001),

http://wet.kuleuven.be/wetenschapinbreedbeeld/lesmateriaal_geologie/wardday-lapalmatsunami.pdf

**Tsunami Society Discounts
this scenario**

SAGE CALCULATIONS OF THE
TSUNAMI THREAT FROM LA PALMA

Galen Gisler

Los Alamos National Laboratory and University
of Oslo

Robert Weaver

Los Alamos National Laboratory,

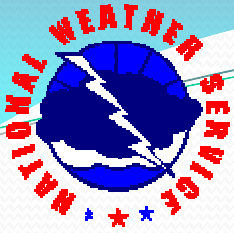
Michael L. Gittings

Science Applications International

<http://www.tsunamisociety.org/244gisler.pdf>

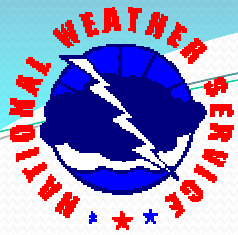


Probabilities & Risk



What is the Probability of a Tsunami Along the Atlantic or Gulf Coasts?

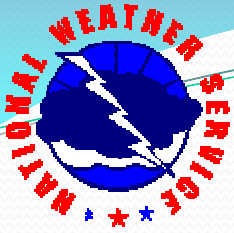
1.0 – Certain to Occur



What is the Return Interval and Magnitude of Tsunami's in the Gulf or Atlantic?

We don't know!

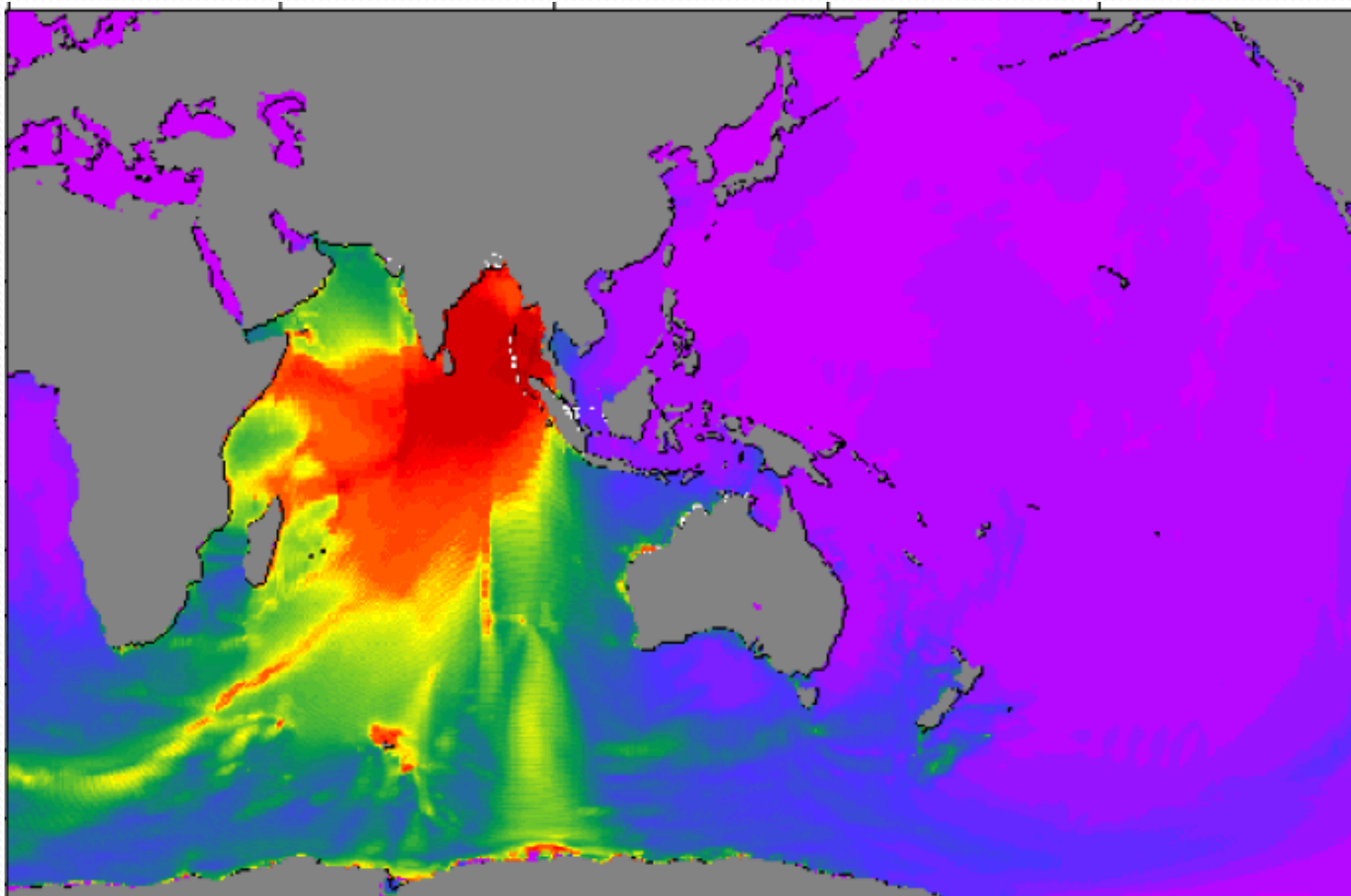




In October 2003, Australian seismologist, Phil Cummins, Predicated there will be a Massive earthquake and tsunami near Sumatra, and its just a matter of time. Therefore we must implement an Indian Ocean Tsunami Warning system!



The Tsunami Struck the following year!



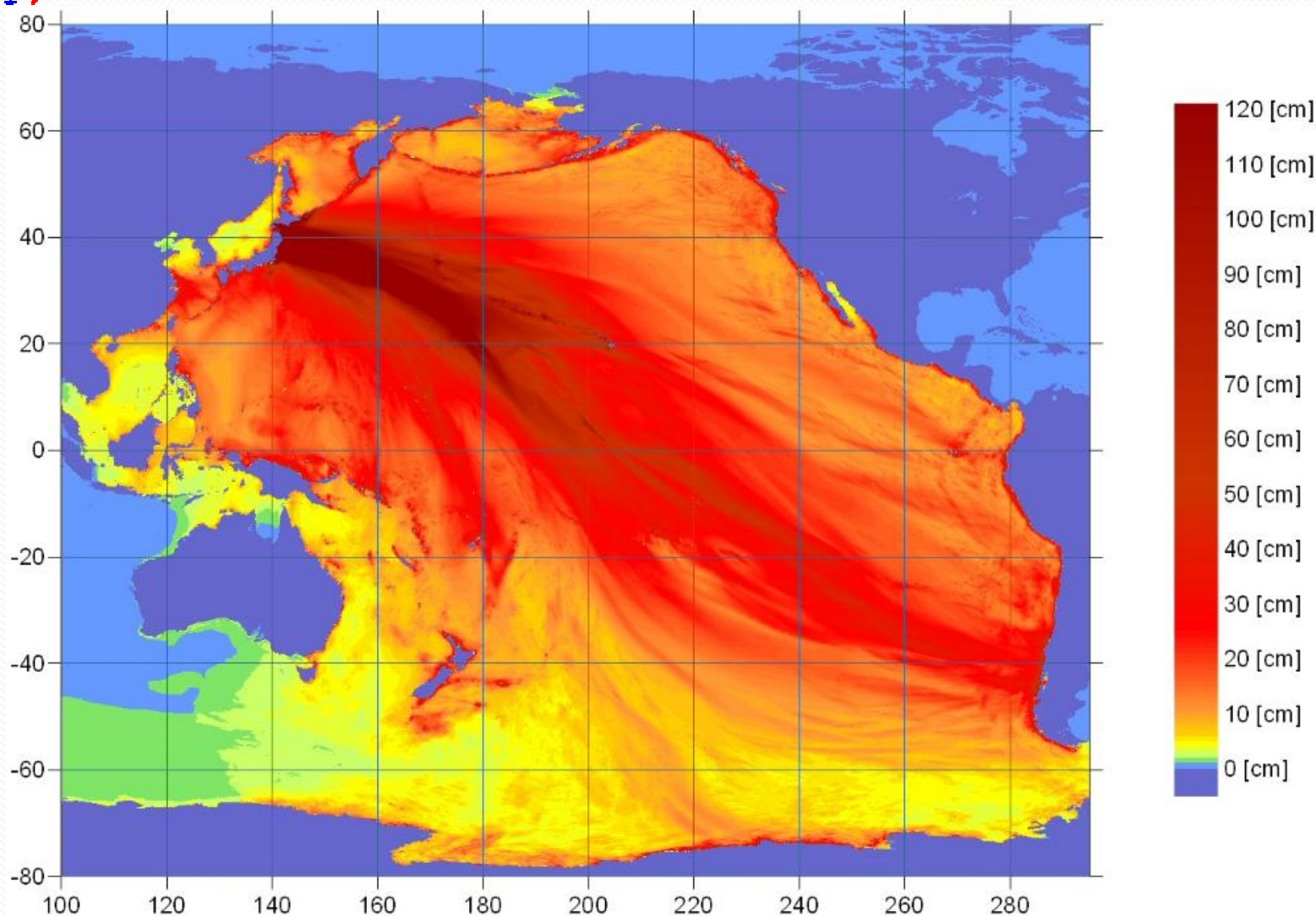
December 26th, 2004





Japan Tsunami - Another Wake Up Call

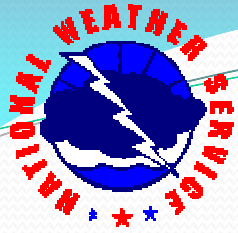
March 11, 2011



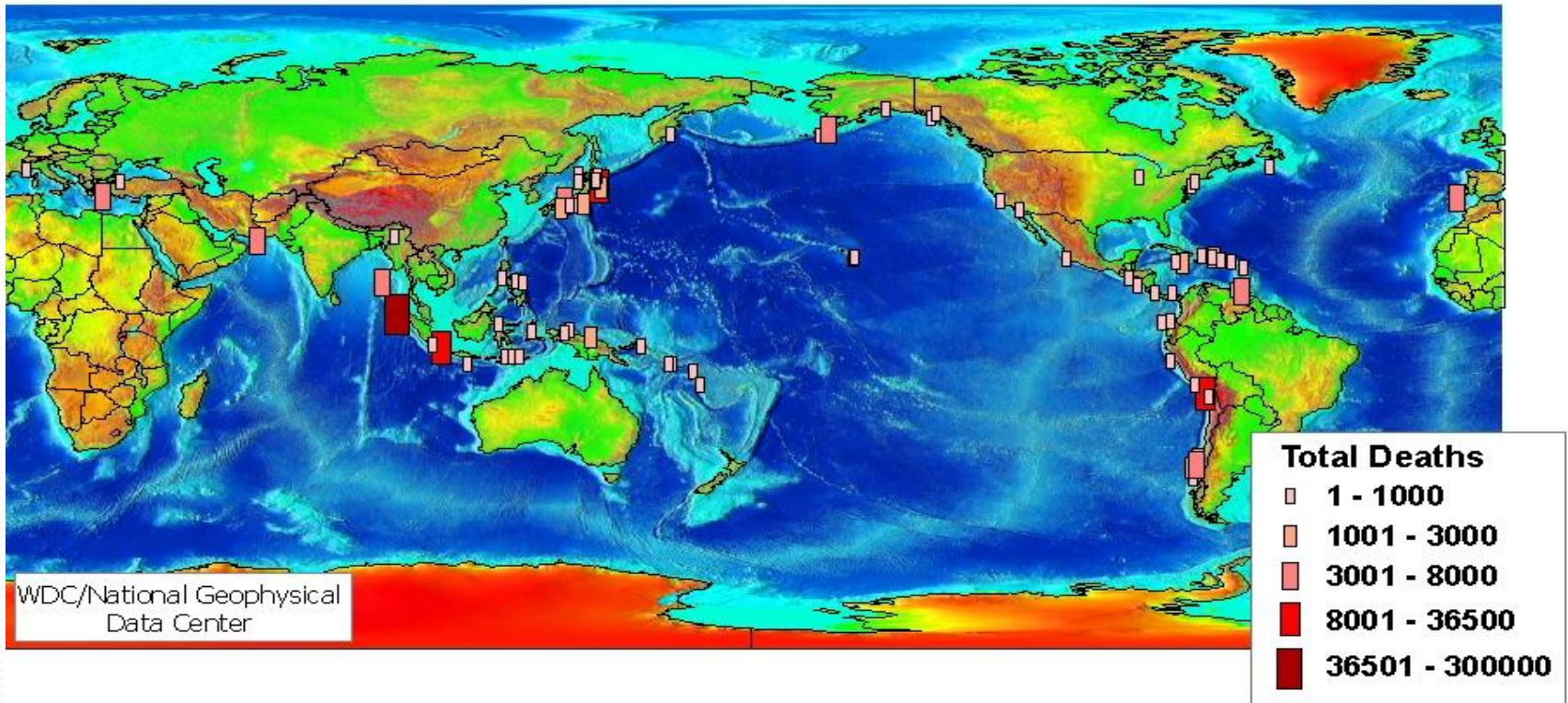


Tsunami Approaching Japan





Tsunami Events Causing Deaths

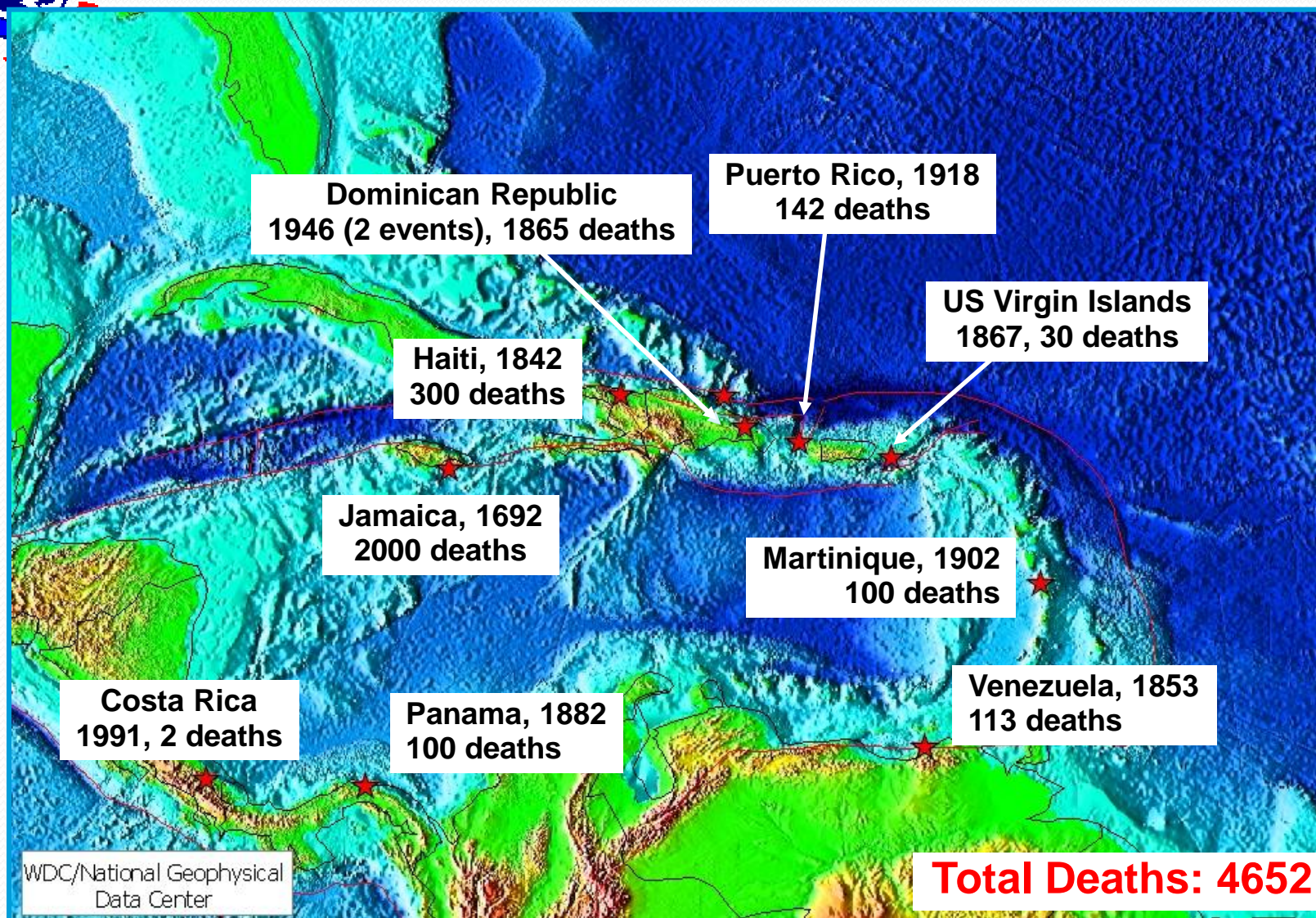


190 source events from 744 - 2007

Courtesy of Paula Dunbar, 2007



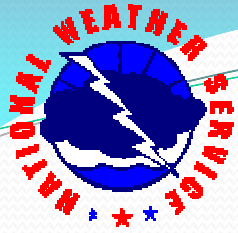
Caribbean Tsunamis Fatalities 1692 to the present



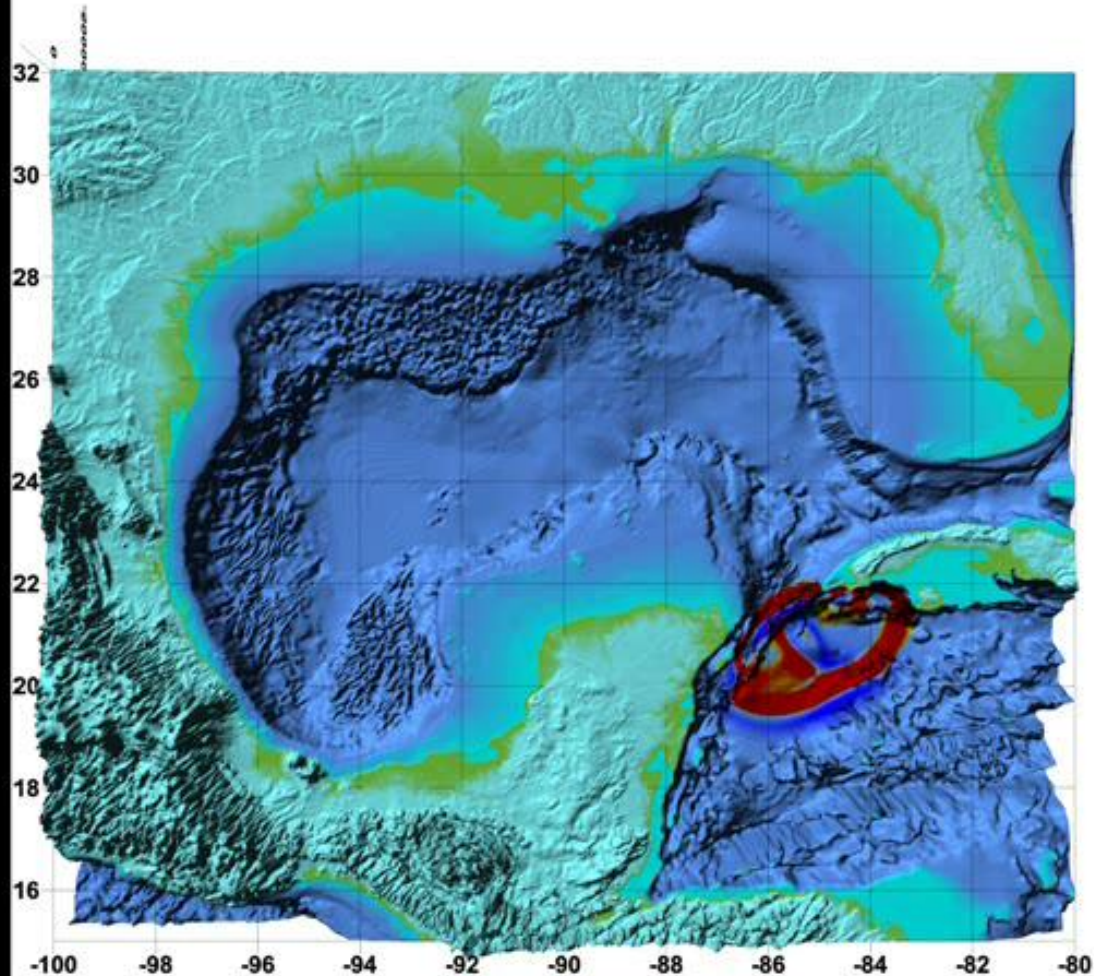
Courtesy of Paula Dunbar, 2007

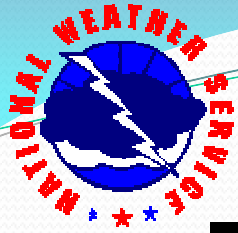


Gulf of Mexico Threat?

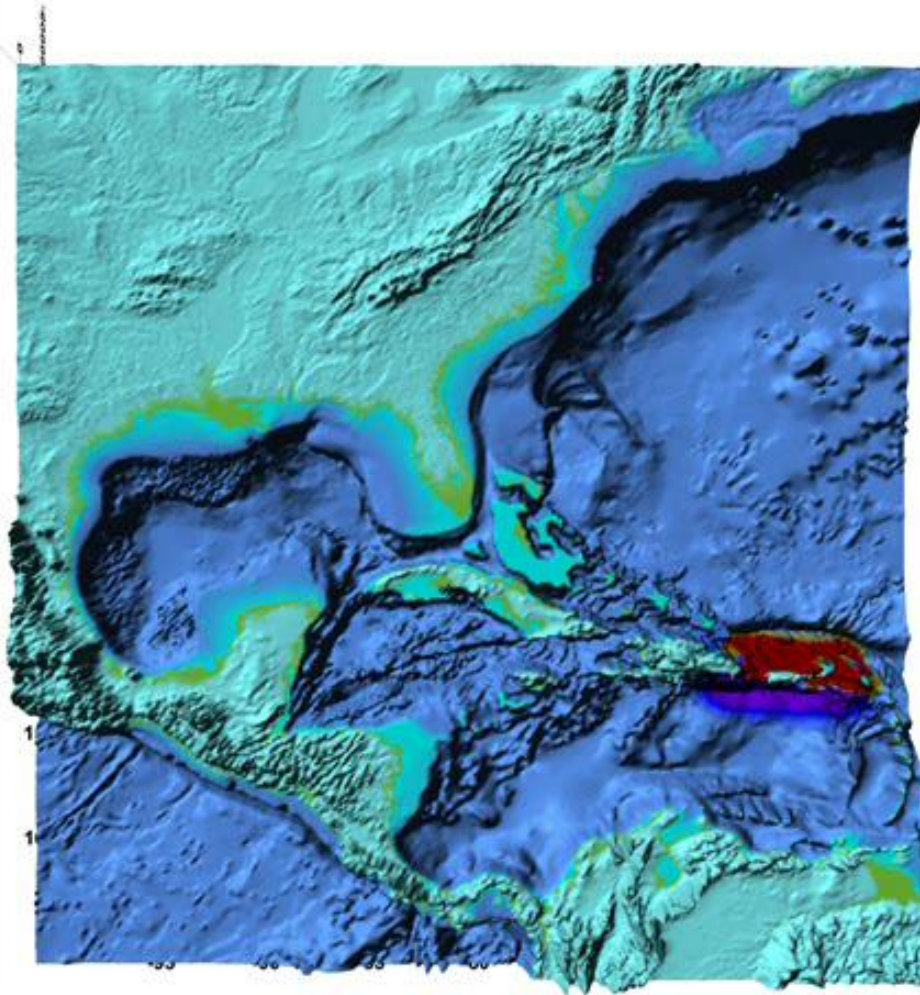


Earthquake in Caribbean?

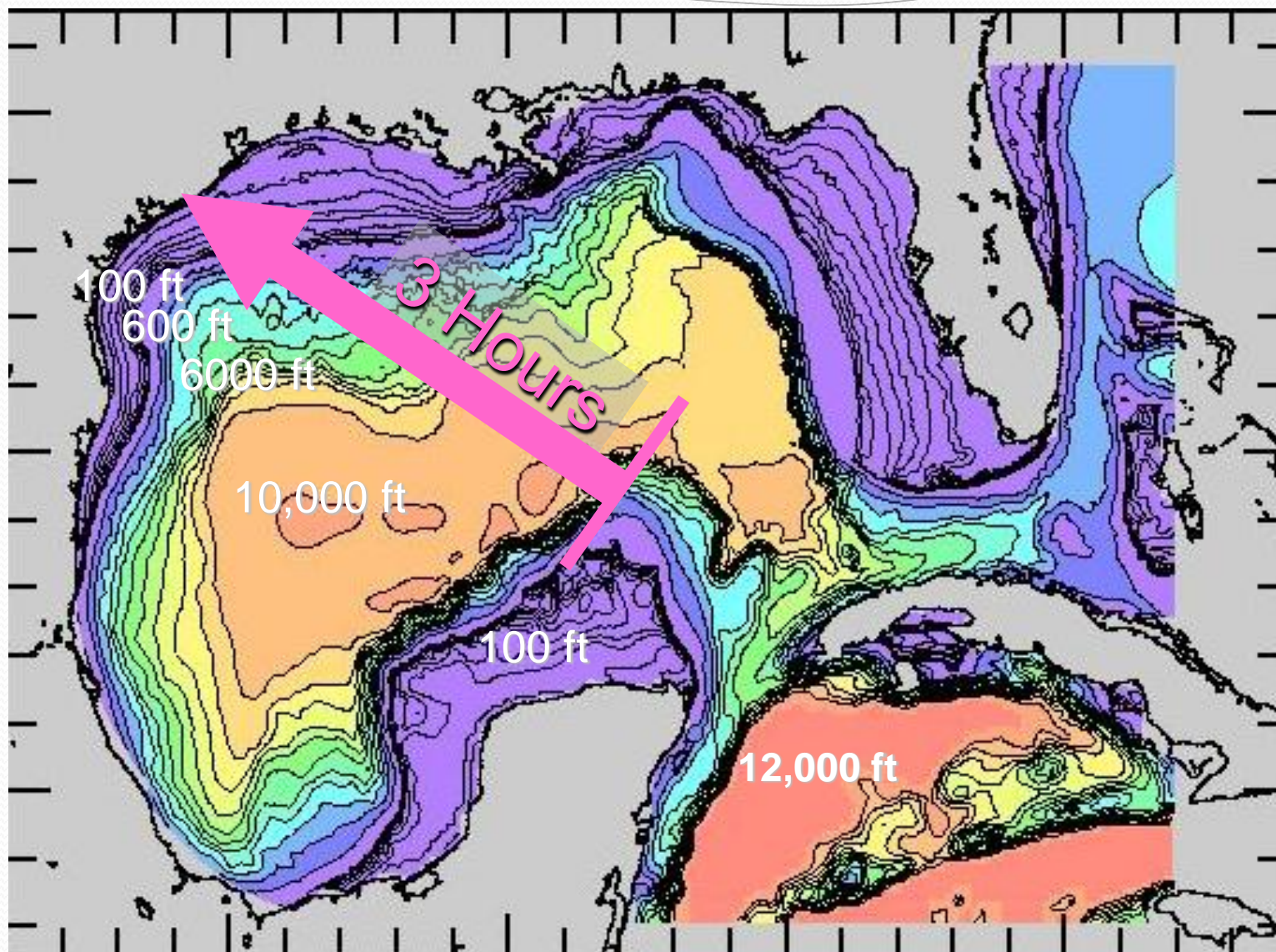




Earth Quake in Puerto Rico



Gulf Tsunami Response Time

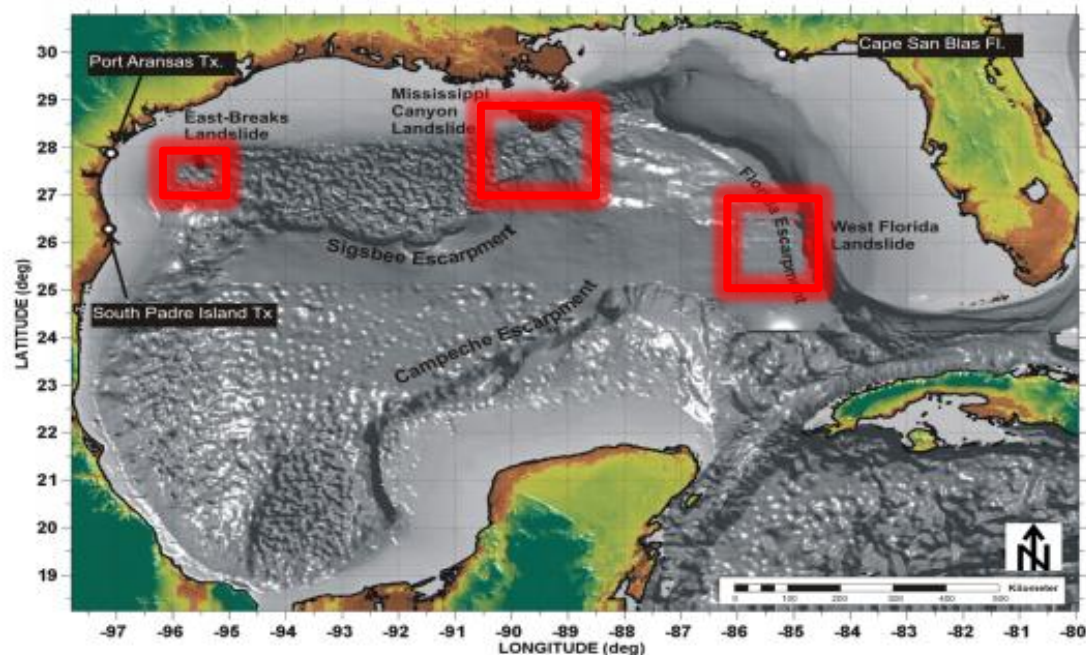


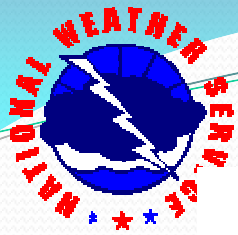


USGS and Texas A&M Study

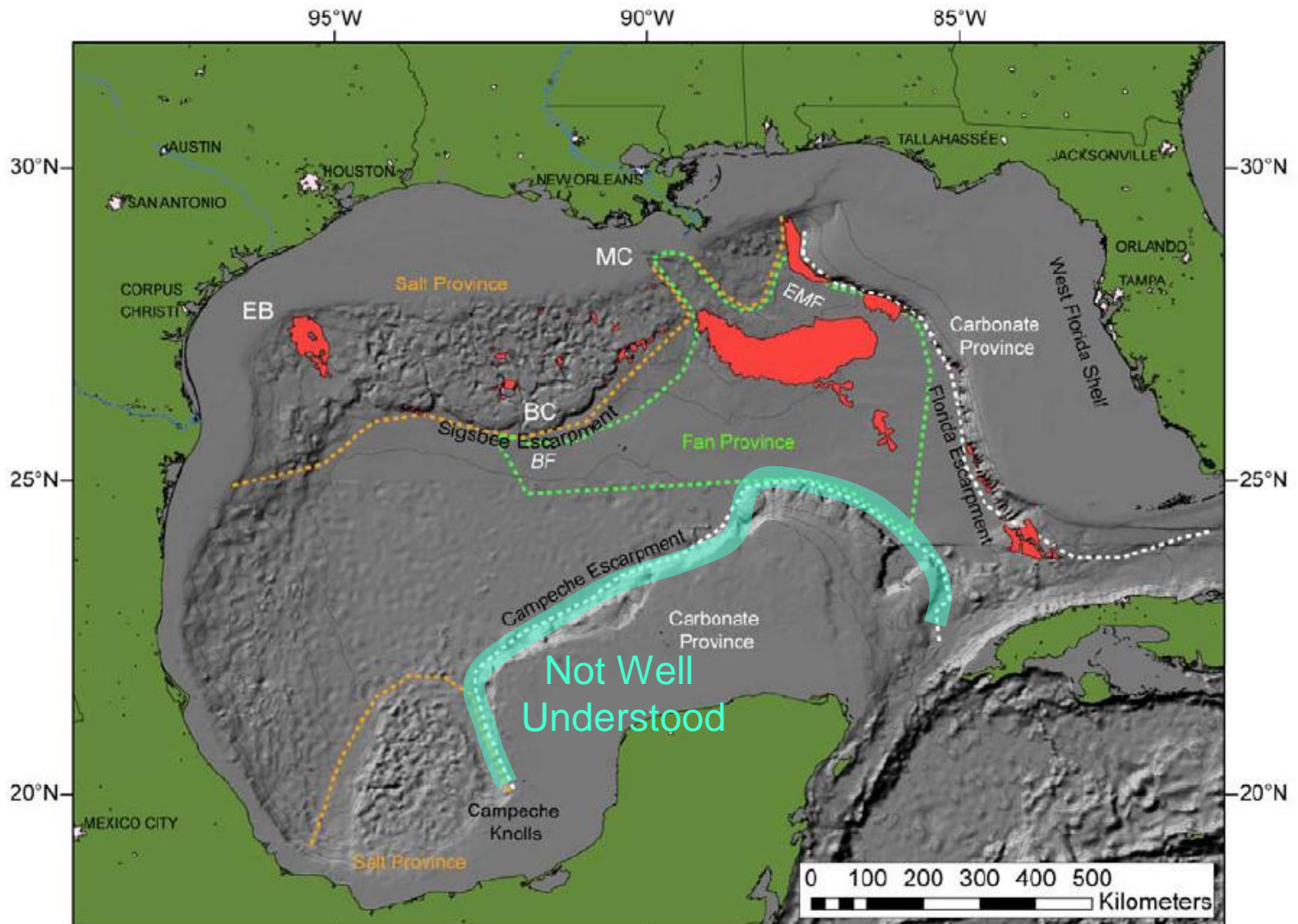
Landslide Tsunami Hazards in the Gulf of Mexico

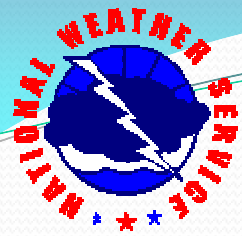
According to the THAG report *Regional Assessment of Tsunami Potential in the Gulf of Mexico*, there are not records which accurately date when these landslides occurred in the past, making difficult to determine what environmental or temporal conditions caused them. However, the report provides a detailed description of the geological provinces in the GOM that are likely to be the origin of submarine landslides. These provinces feature the three major ancient scarps or excavations with their respective sediment depositions down slope that were capable of generating large tsunamis in the past: The three underwater landslides are: East-Breaks, Mississippi Canyon and West Florida landslides, see Figure 1.





Landslide Tsunami Potential





Evidence of Landslides in Gulf of Mexico

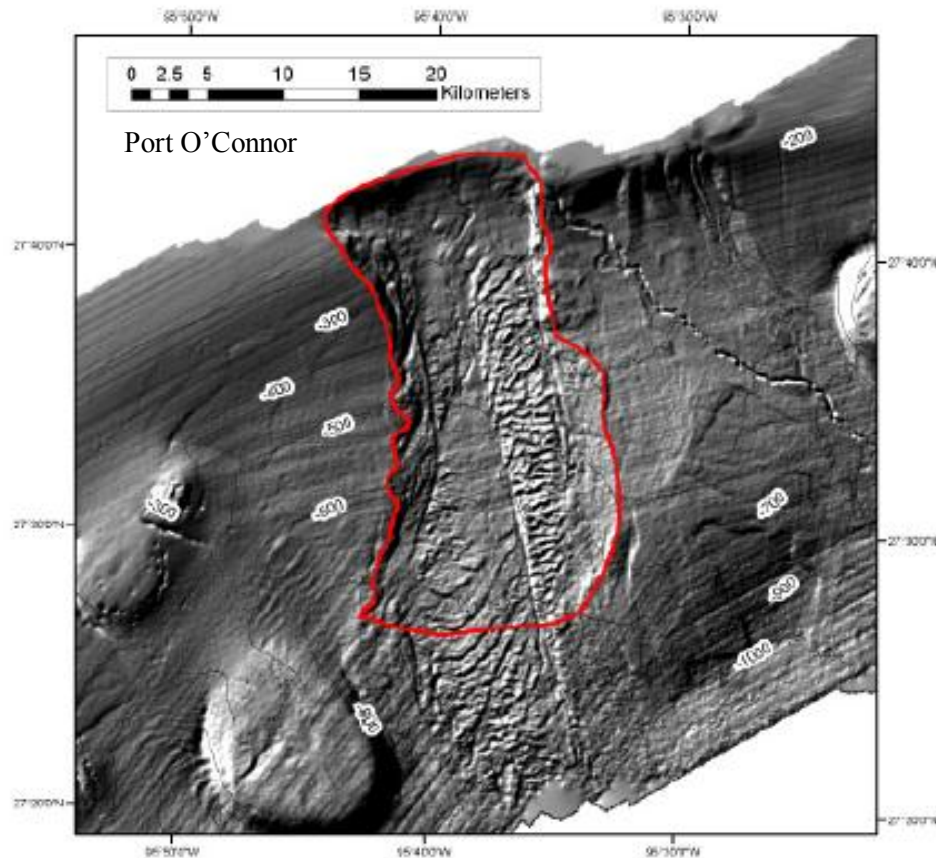


Figure 3-2: Outline (red) of excavation area for the East Breaks landslide based on available multibeam bathymetric data.

East Breaks – NW Gulf of Mexico

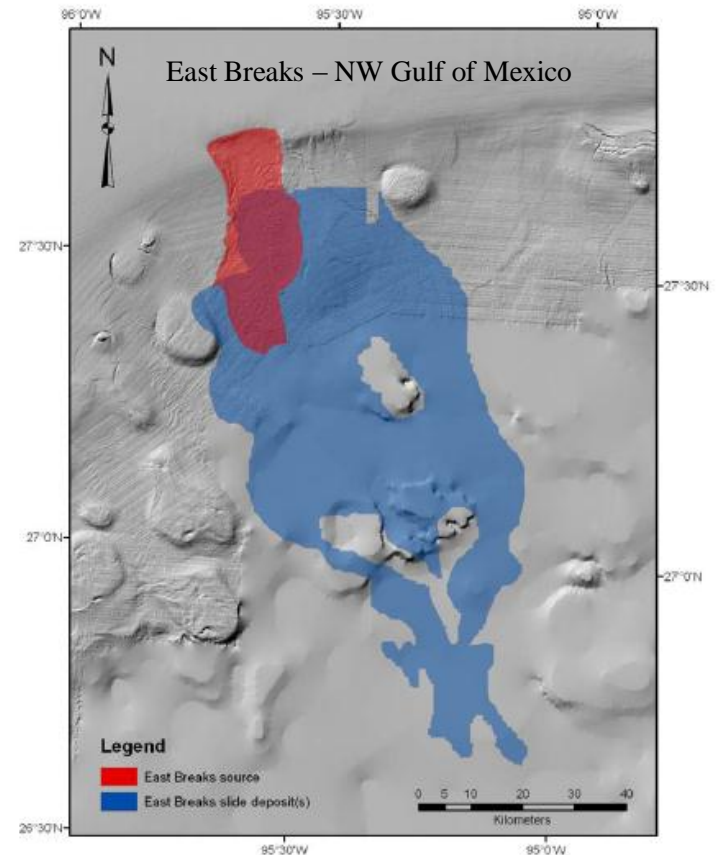
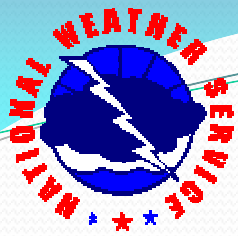
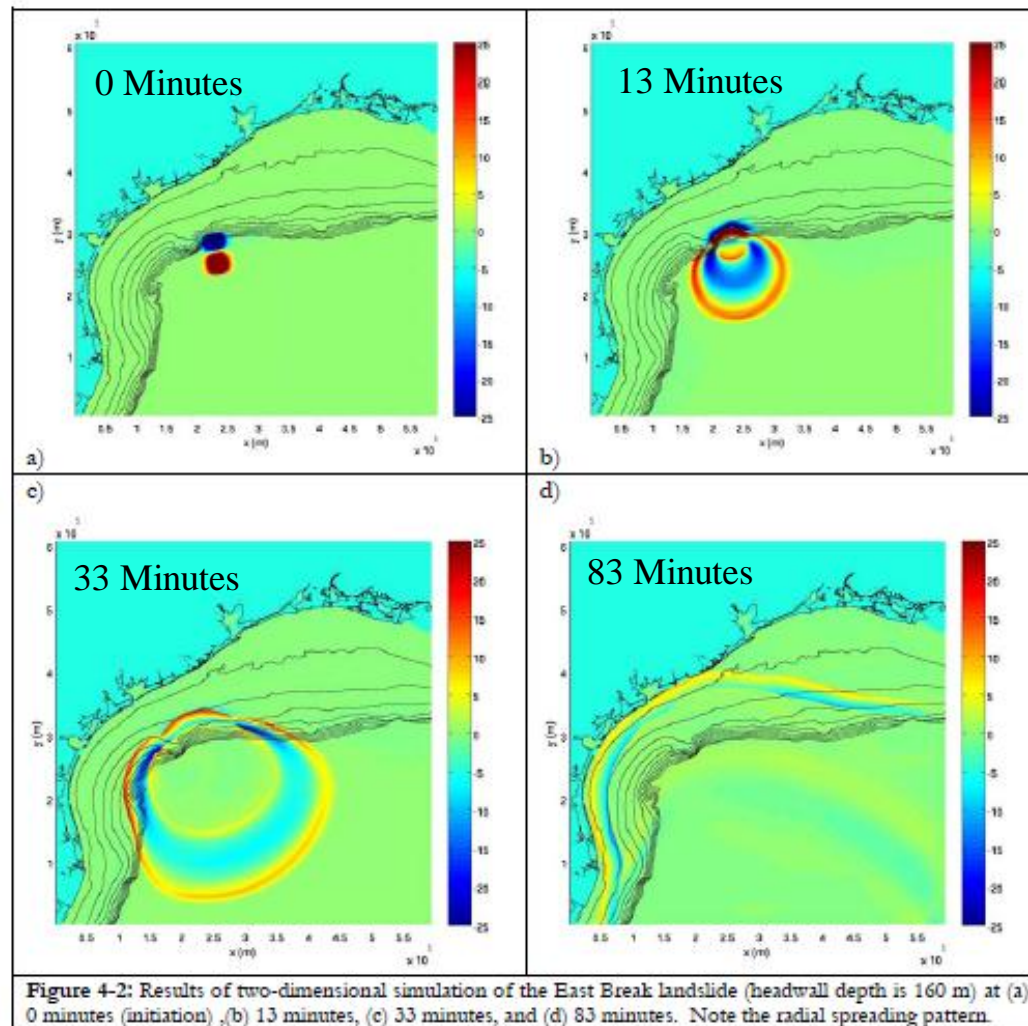
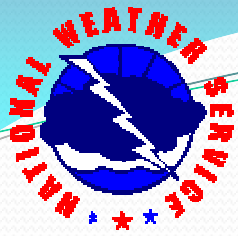


Figure 3-3: Comparison of excavation area (red) and depositional area (blue) for the East Breaks landslide. The extent of the landslide deposit was mapped using GLORIA sidescan sonar imagery (Rothwell et al., 1991).

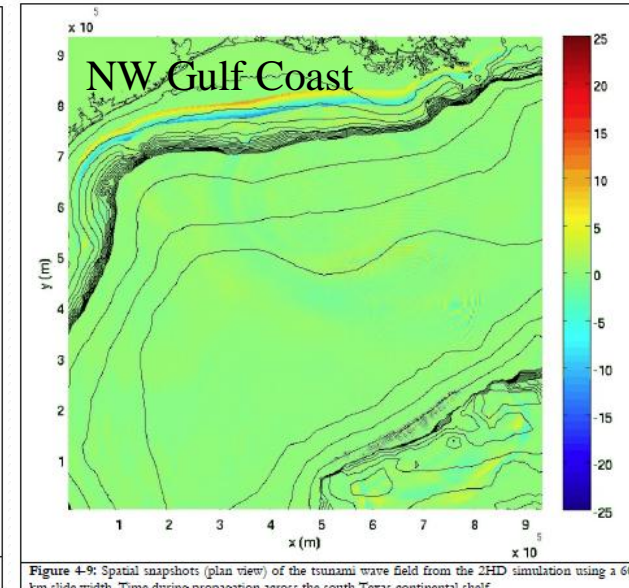
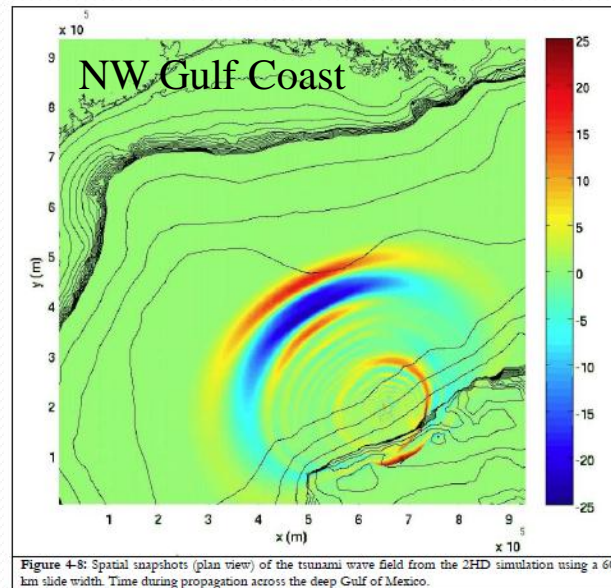
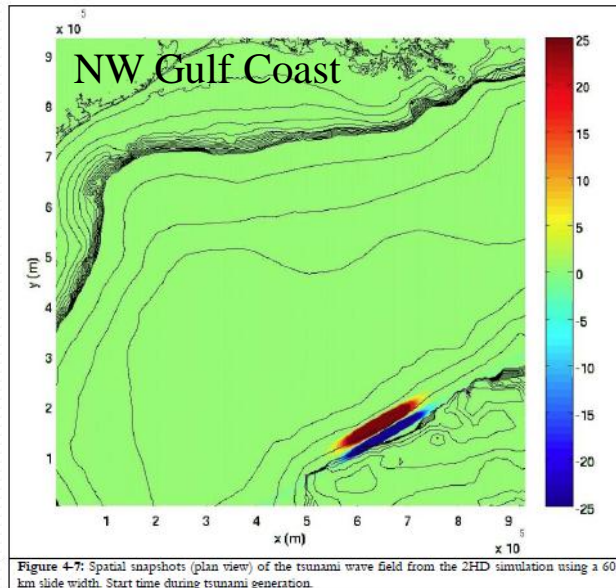


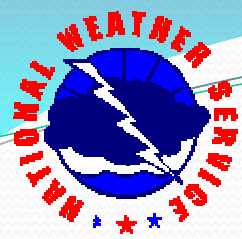
Hypothetical Landslide Modeling





Hypothetical Landslide Modeling





Evidence of Landslides in Gulf of Mexico

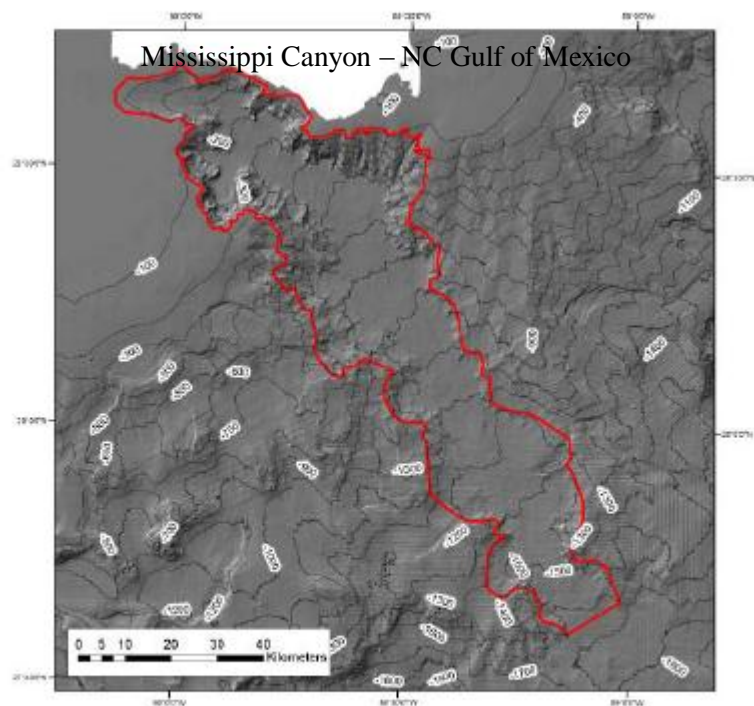


Figure 3-4: Outline (red) of excavation area for the Mississippi Canyon landslide based on multibeam bathymetric data and reports by Coleman and others (1983) and Goodwin and Prior (1989).

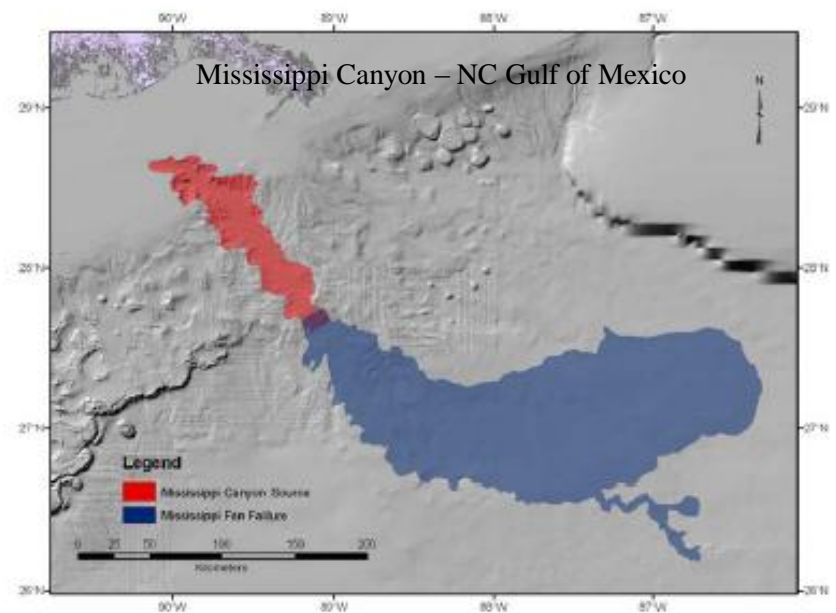


Figure 3-5: Comparison of excavation area (red) and depositional area (blue) for the Mississippi Canyon landslide. The extent of the landslide deposit is based on GLORIA sidescan sonar imagery (Twichell et al., 1991).

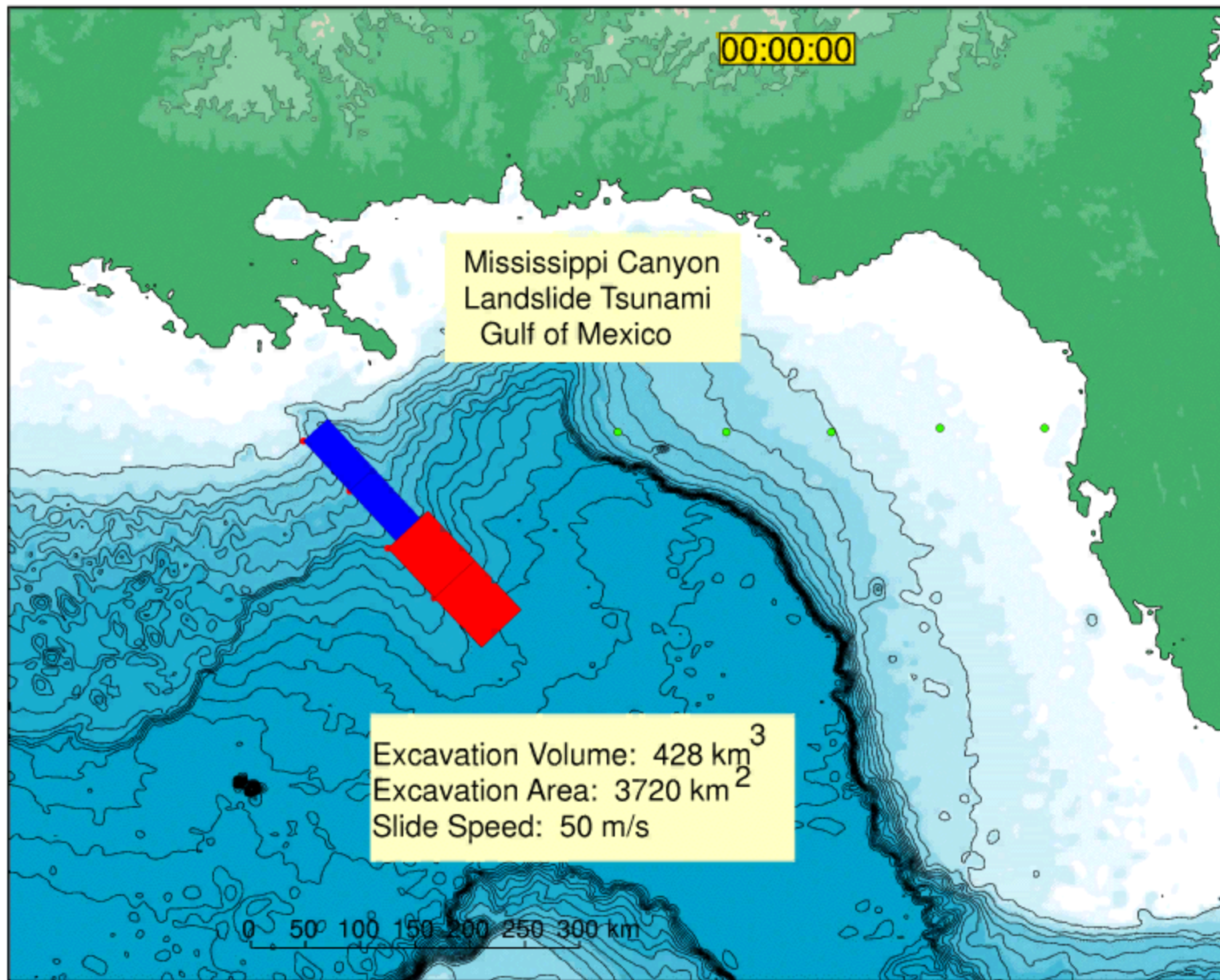


00:00:00

Mississippi Canyon
Landslide Tsunami
Gulf of Mexico

Excavation Volume: 428 km^3
Excavation Area: 3720 km^2
Slide Speed: 50 m/s

0 50 100 150 200 250 300 km



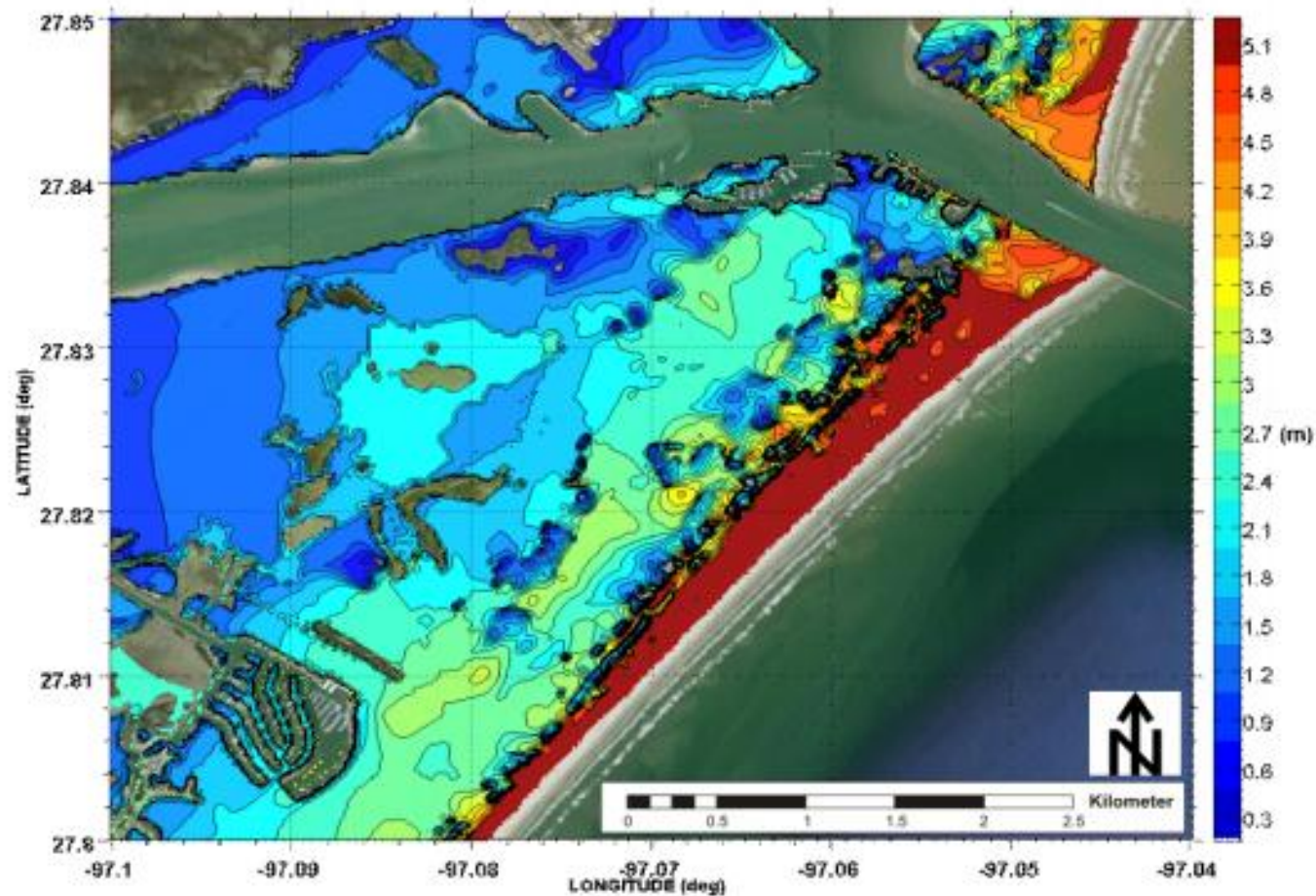
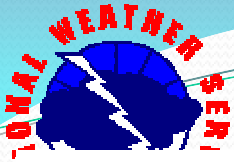


Figure 3: Maximum water depth caused by the Mississippi Canyon landslide in Port Aransas



Port Aransas Tsunami Inundation

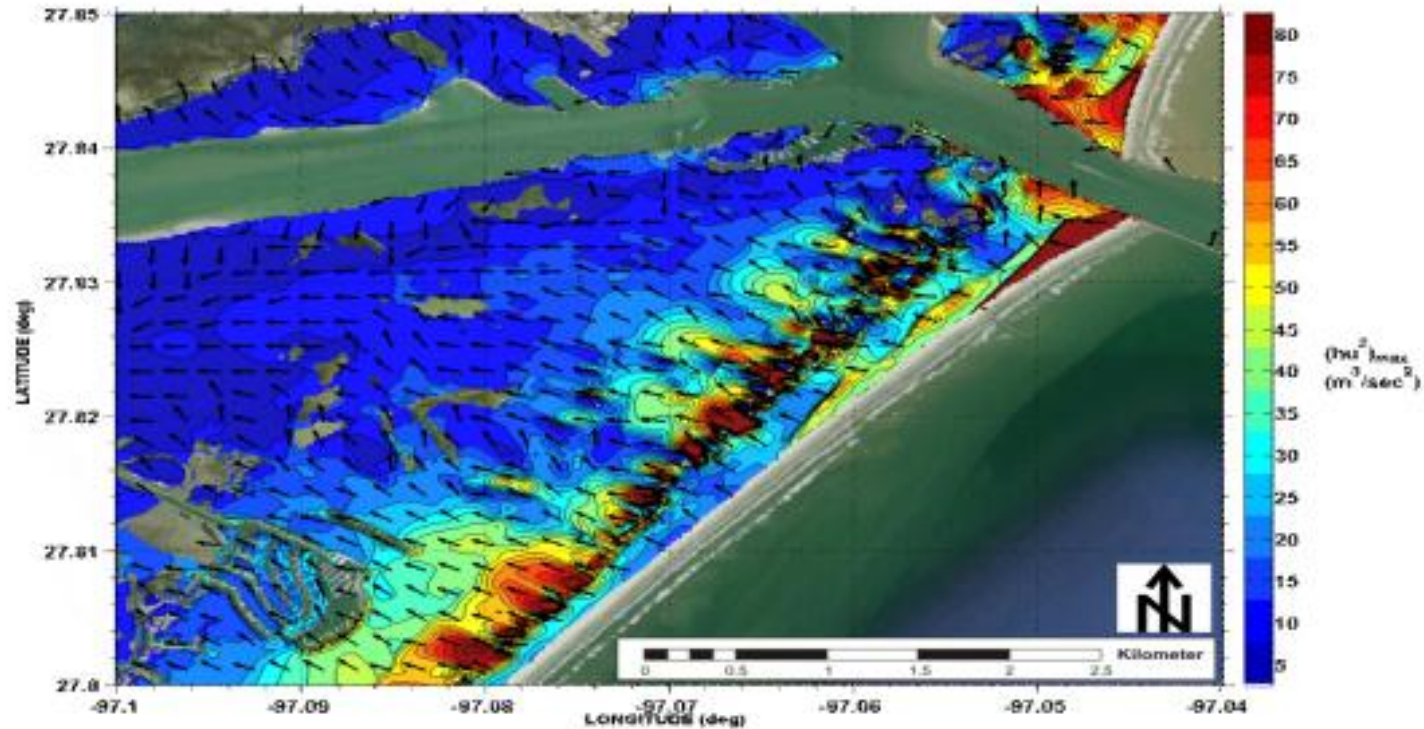
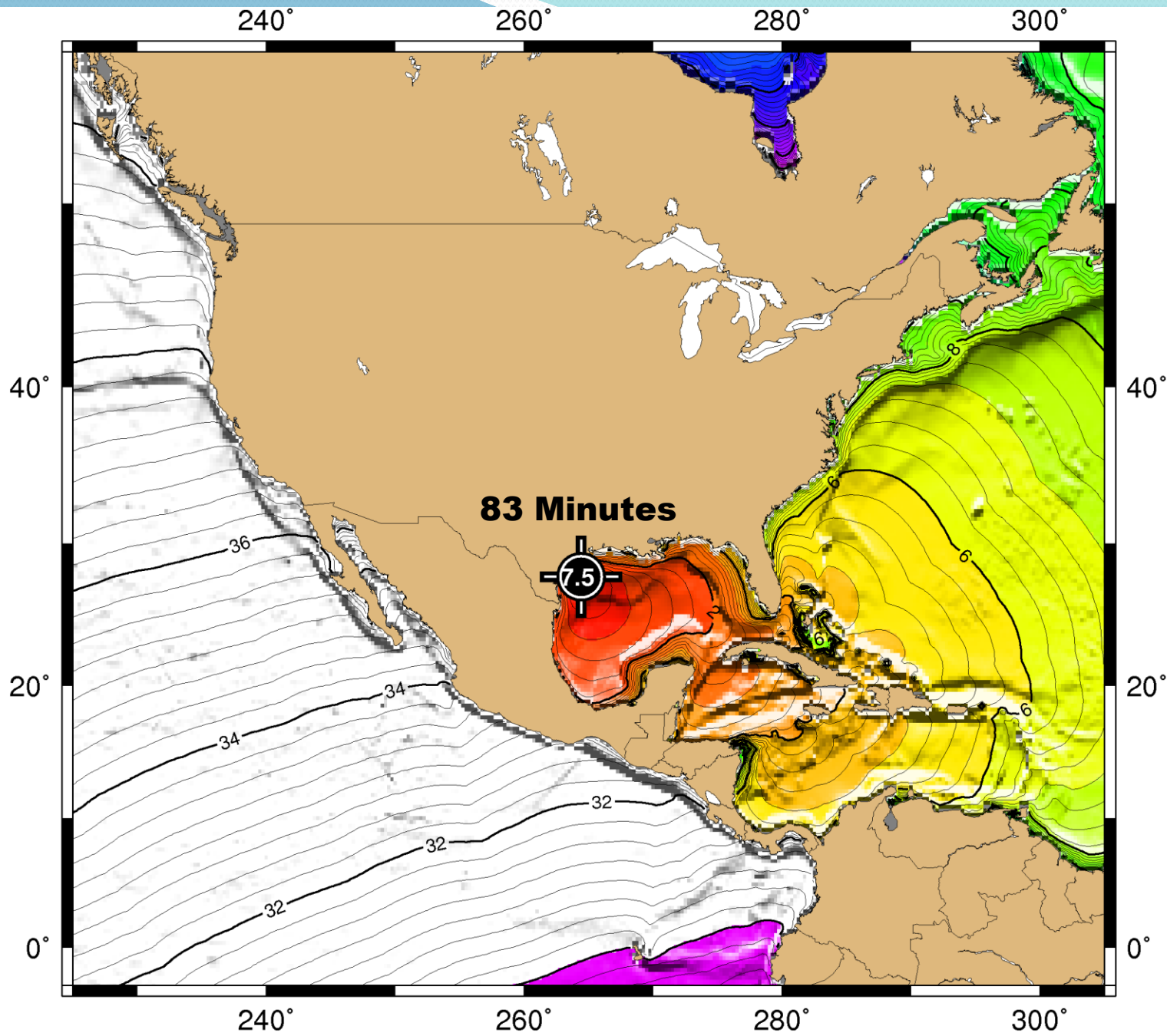
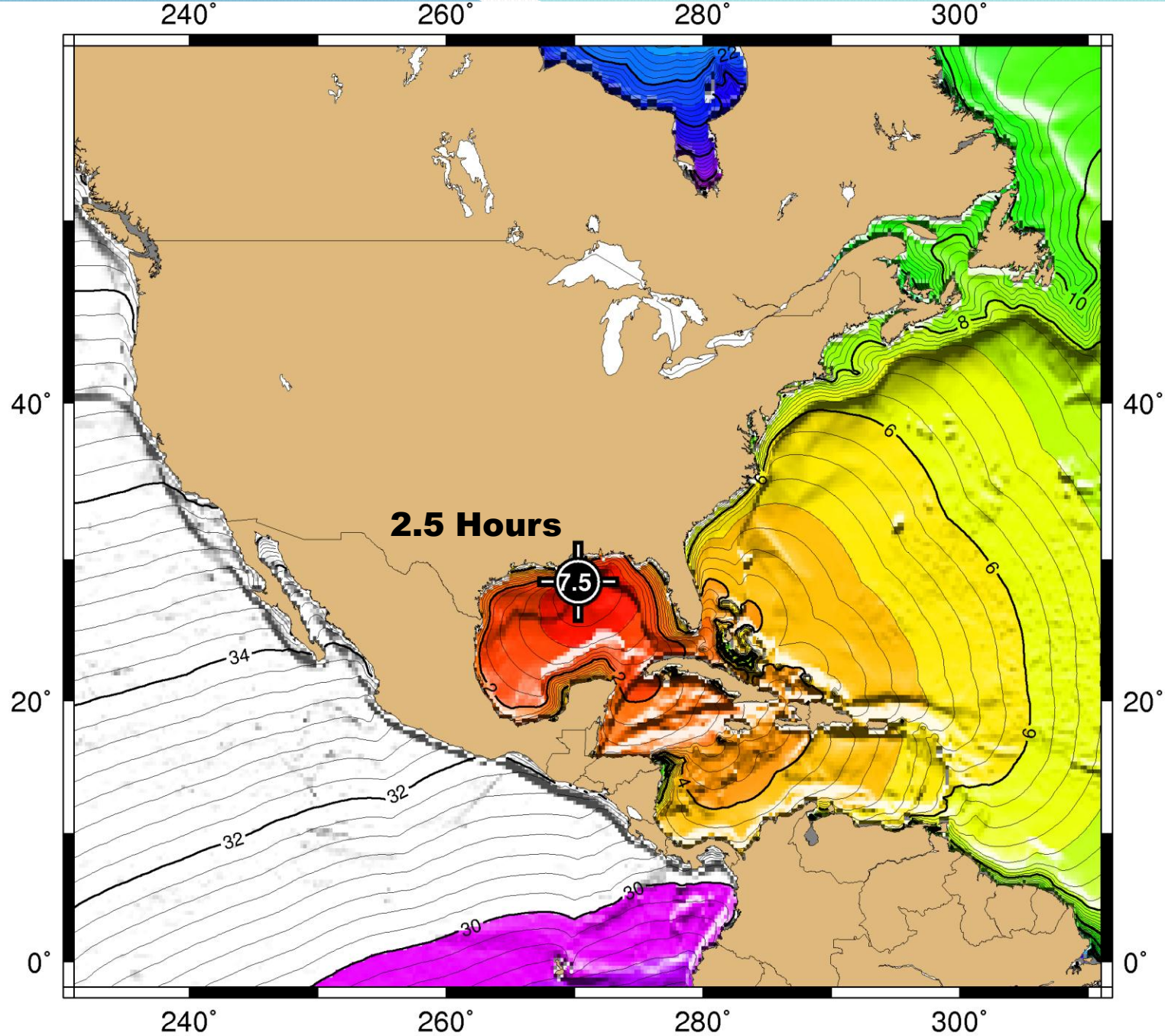
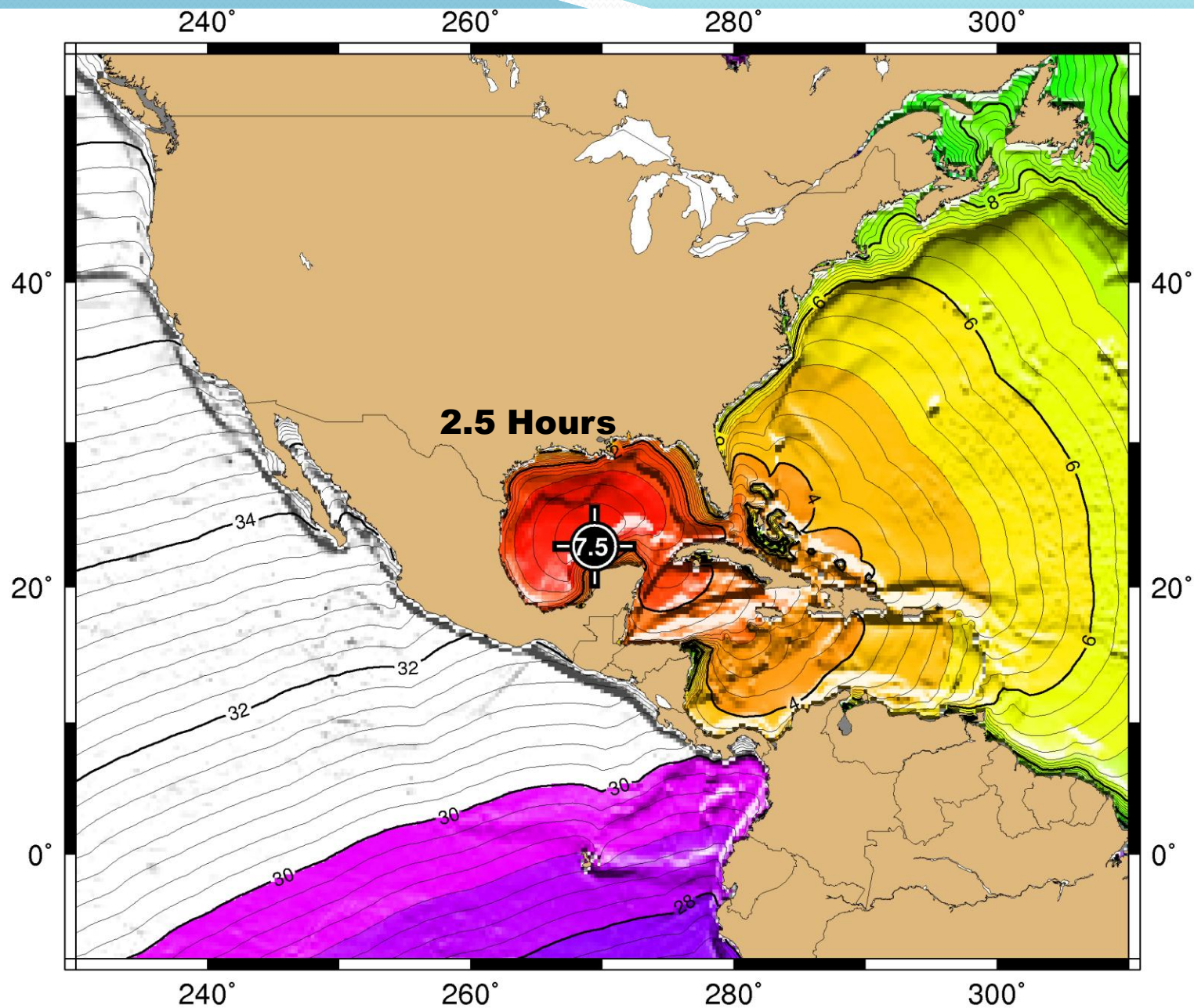


Figure 4: Maximum tsunami momentum flux caused by the Mississippi Canyon landslide in Port Aransas. Arrows represent momentum flux direction

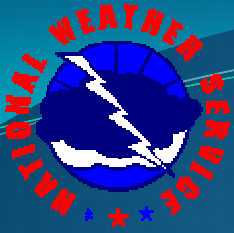






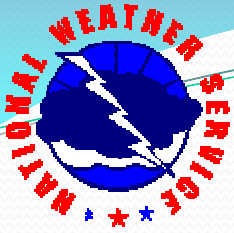
2013 Feb 06 13:47:07

TSUNAMI TRAVEL TIMES USING POINT SOURCE (EPICENTER), ● = Past EQ, ▲ = Coastal Gauge, ▼ = Deep-ocean Gauge



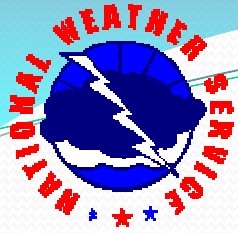
Warning Signs

Tsunami Approach



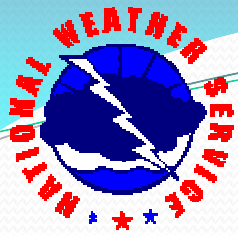
Natural Warning Signs of a Tsunami

- **Feel the earth shake.** A large undersea earthquake may be felt prior to tsunami by an ongoing shaking of the ground in coastal regions. However, you may not feel an earthquake if the source is far away.
- **See the ocean drop.** As tsunami approach the shoreline, the sea level may, but not always, recede/drop dramatically before returning as a fast-moving wall of water.
- **Hear an unusual roaring sound.** A roaring sound may precede the arrival of tsunami.



Small Tsunami Impact





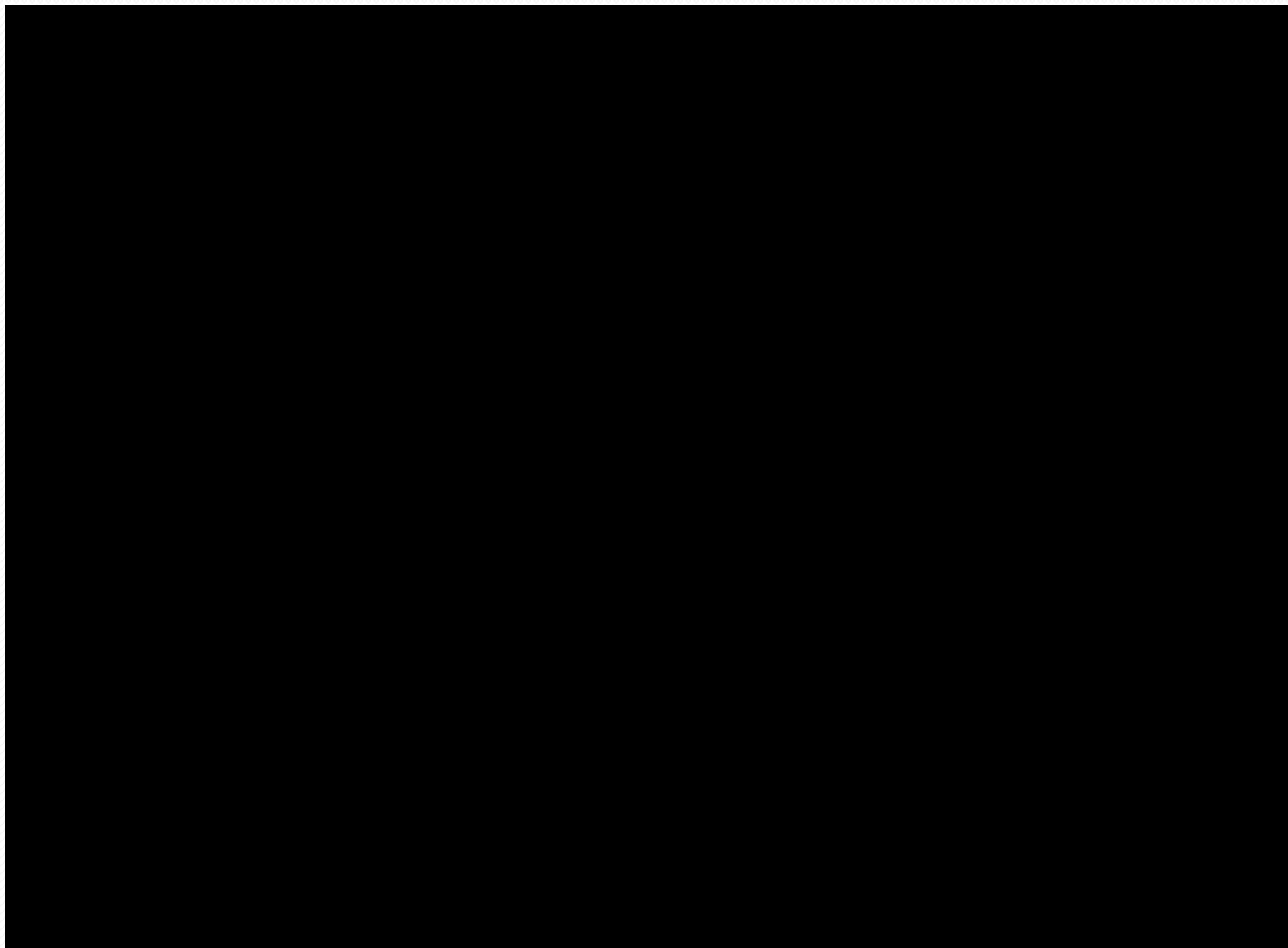
Mega Tsunami Approach

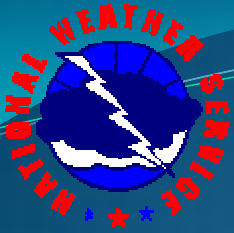


Indonesia, December 2004



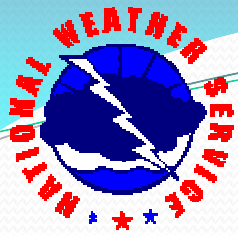
Mega Tsunami Approach





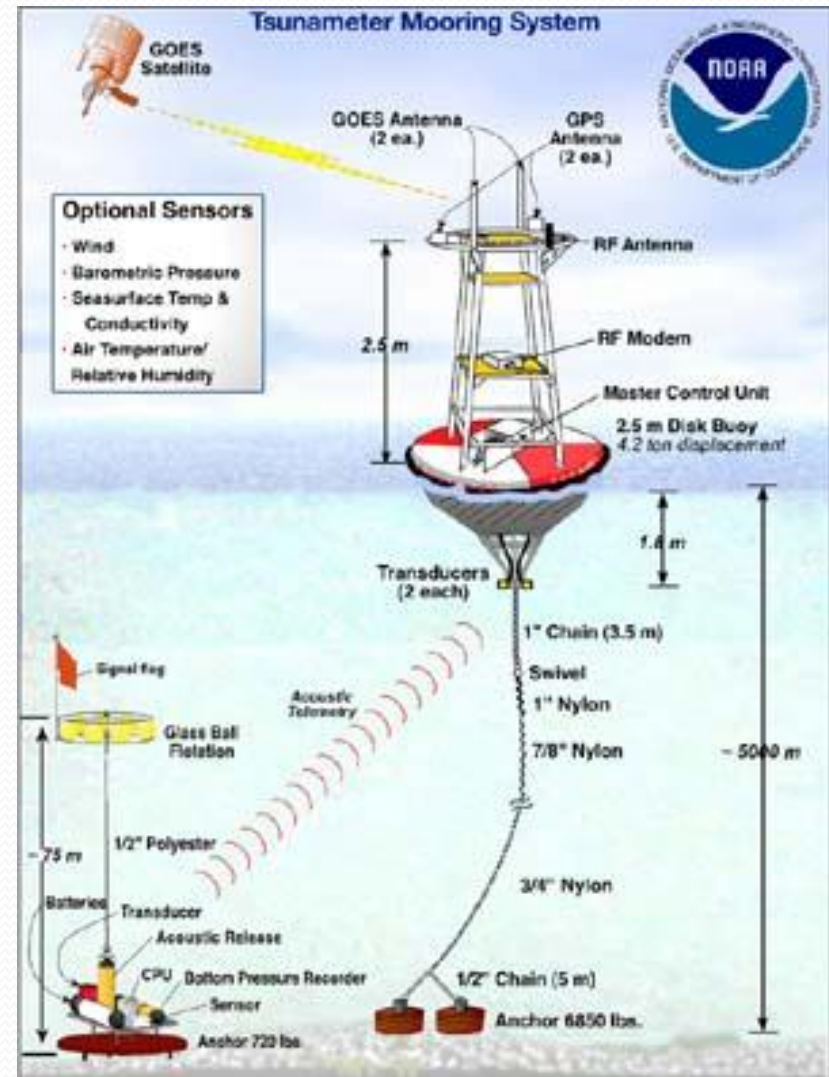
Tsunami

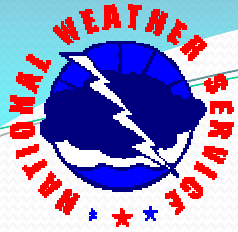
Warning System



U.S. Tsunami Warning System

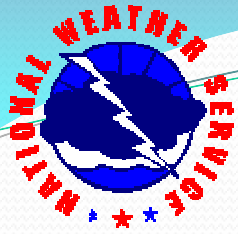
- Tsunami Warnings Issued for Threatened Areas in U.S. (Example: West Coast 6/14/05)
- National Weather Service Tsunami Warning Centers (Alaska, Hawaii)
- Local NWS Offices Issue Local Advisories & Evacuation Information
- NWS Tsunami READY Communities
- Tsunami Buoys Network & Video





Tsunami Warning Center





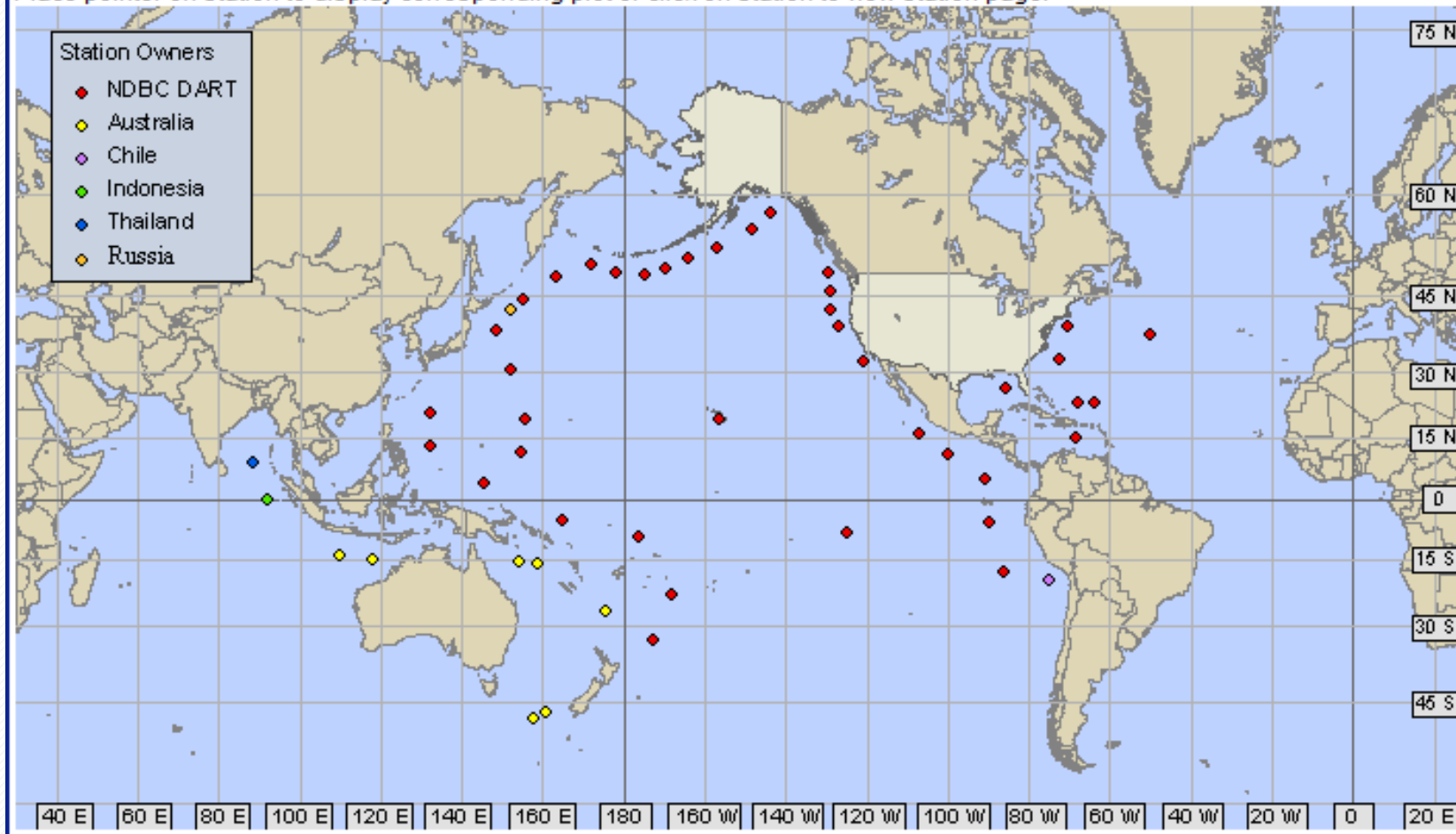
Tsunami Warning Center

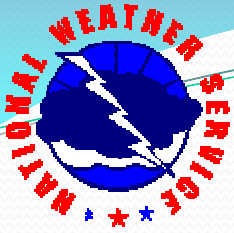




Dart Buoy Locations

Place pointer on station to display corresponding plot or click on station to view station page.



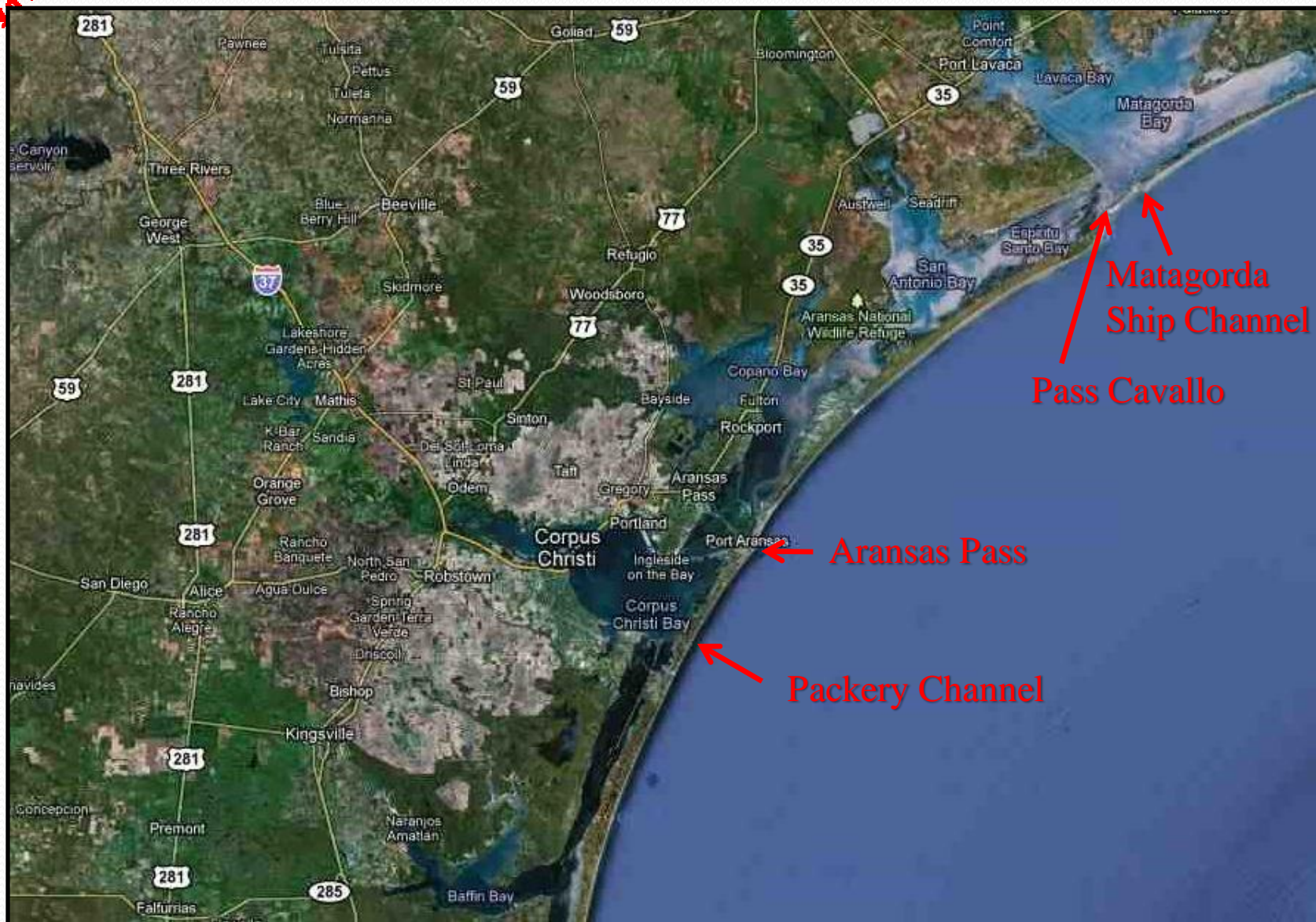


Tsunami

- Large Waves that Result in Tremendous Coastal Damage & Loss of Life
- Result of Offshore Earthquakes, Landslides, Volcanic Activity, Cosmic Impacts
- Greatest Tsunami Threat in Pacific Ocean...but no Ocean Basin is Immune
- National Weather Service Has Warning System in Place to Warn of Tsunami Dangers that Should Help to Limit Mass Fatalities



Barrier Islands and Inlets





Pas



Packery Channel

The Barrier Islands

**San Jose and
Matagorda Island**
- Uninhabited
- Boat access only

Populated area

Padre Island National Seashore
- 40 miles of beach
- One entrance on Northern Side
- Vehicles trapped between dunes and Water
- Evacuation Nightmare



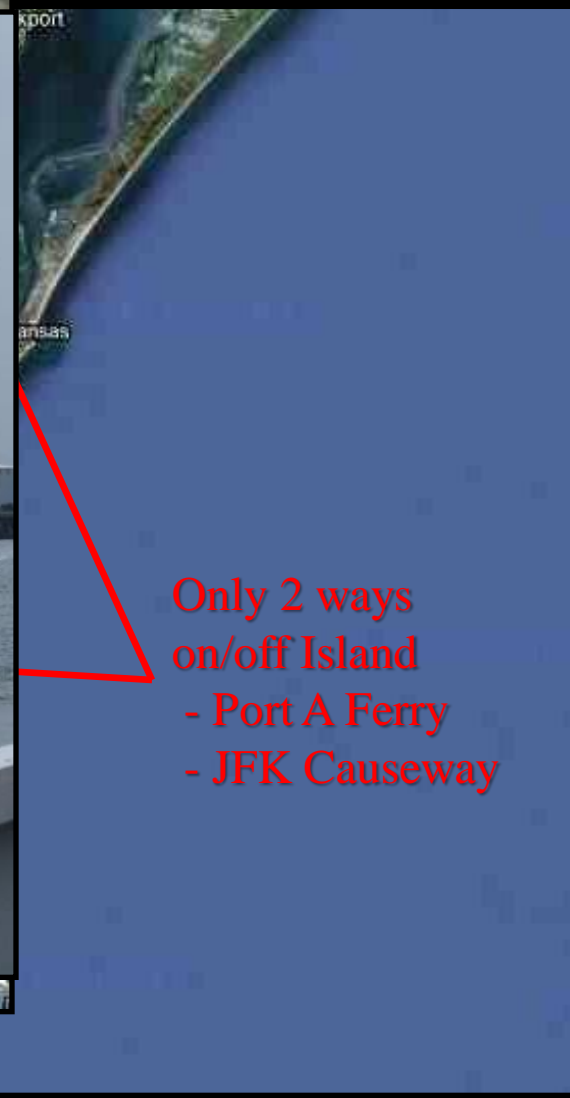


Island Population Centers





Evacuation / Traffic Concerns

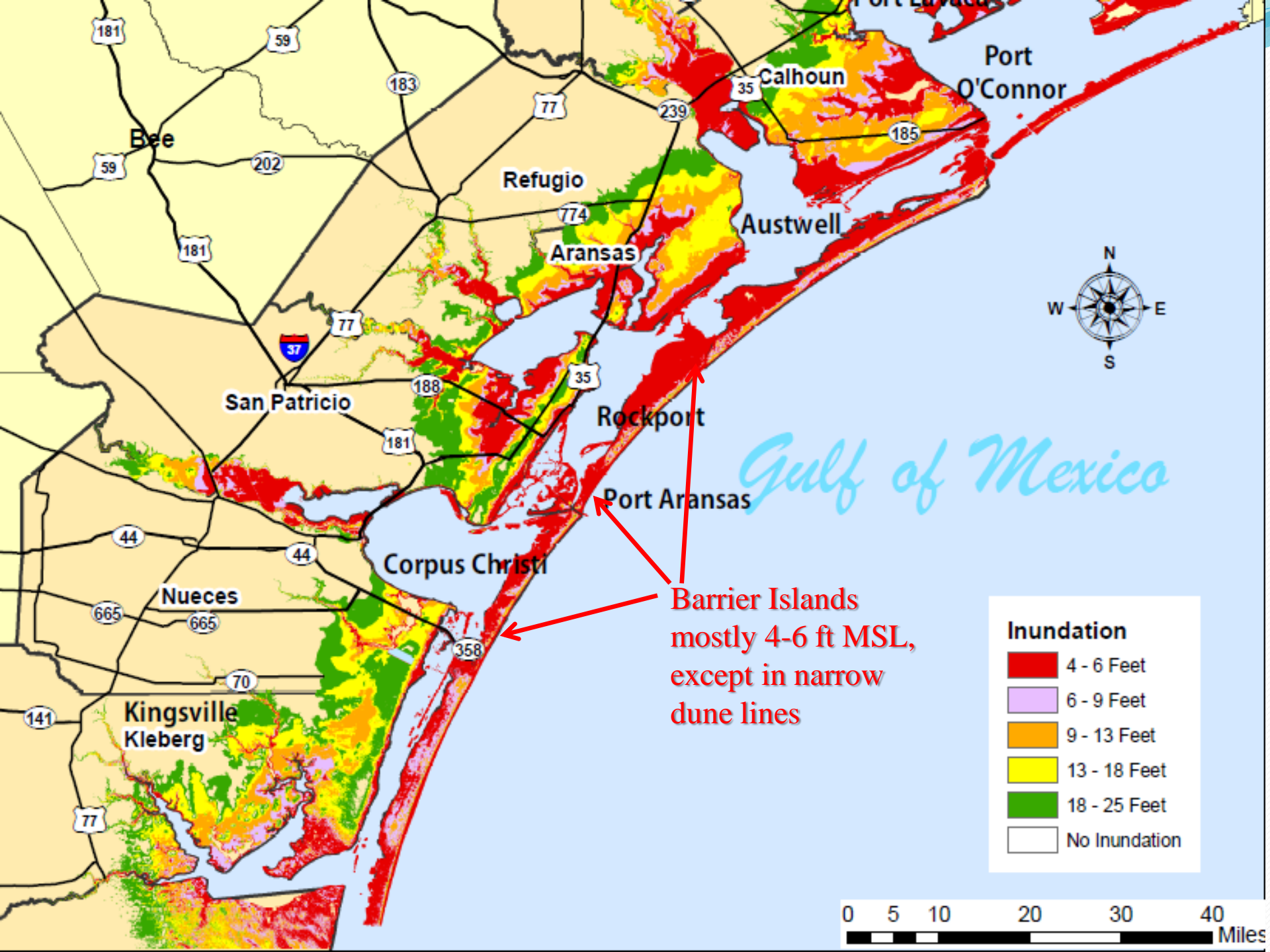


Only 2 ways
on/off Island
- Port A Ferry
- JFK Causeway

Imagery Date: Sep 8, 2003

Image courtesy of Google Earth
27°50'30.92" N 97°04'07.58" W elev: 17 ft

Texas Department of Transportation (TxDOT)



↕ Dunes: 10-20 ft



WCMs Dream

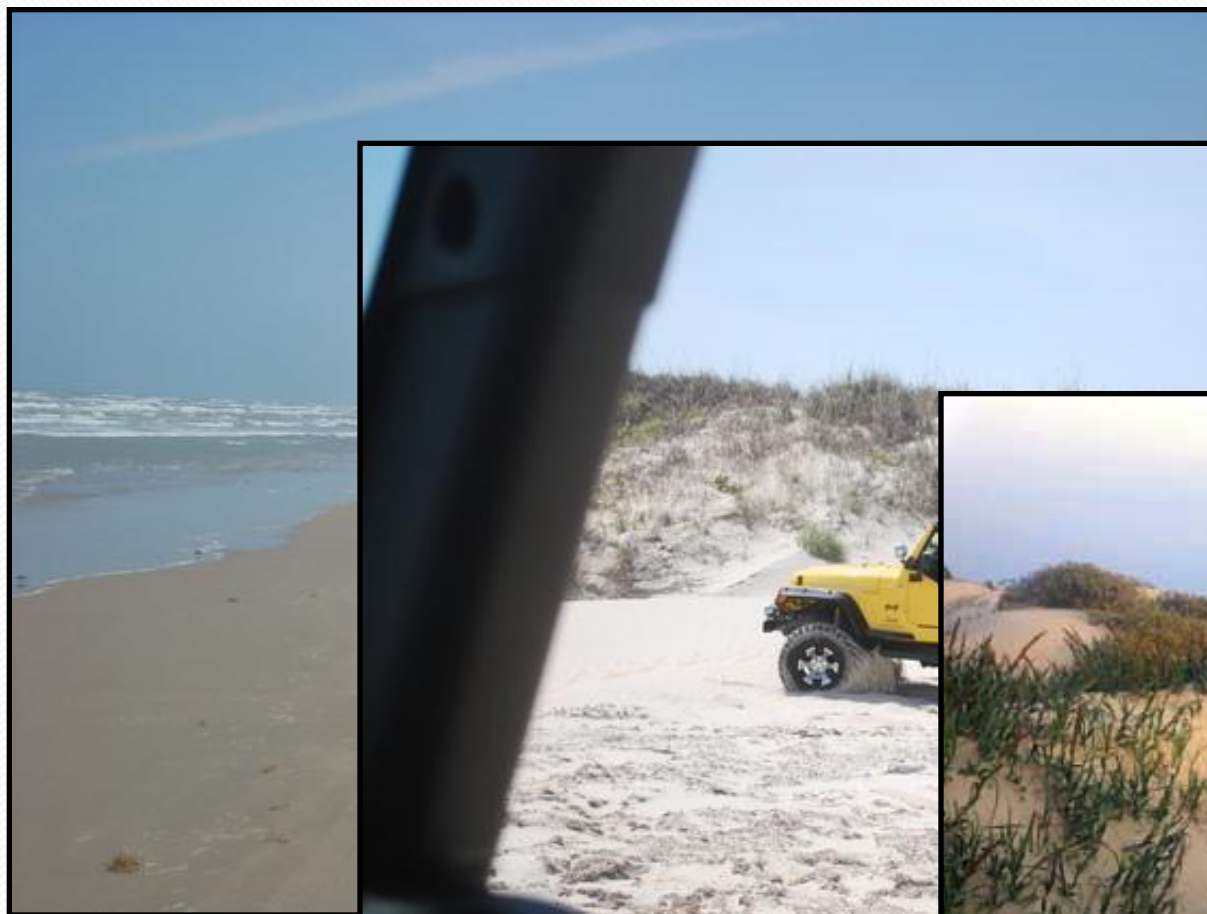
TSUNAMI HAZARD ZONE



Strong earthquake or sea
Level falls abruptly, get to high
ground immediately!



Closer look at the Sand Dunes



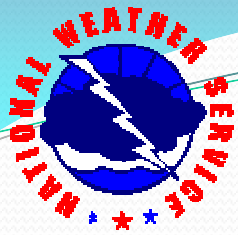
If you feel a Strong Earthquake at the beach...
***Get to High Ground
Immediately!***



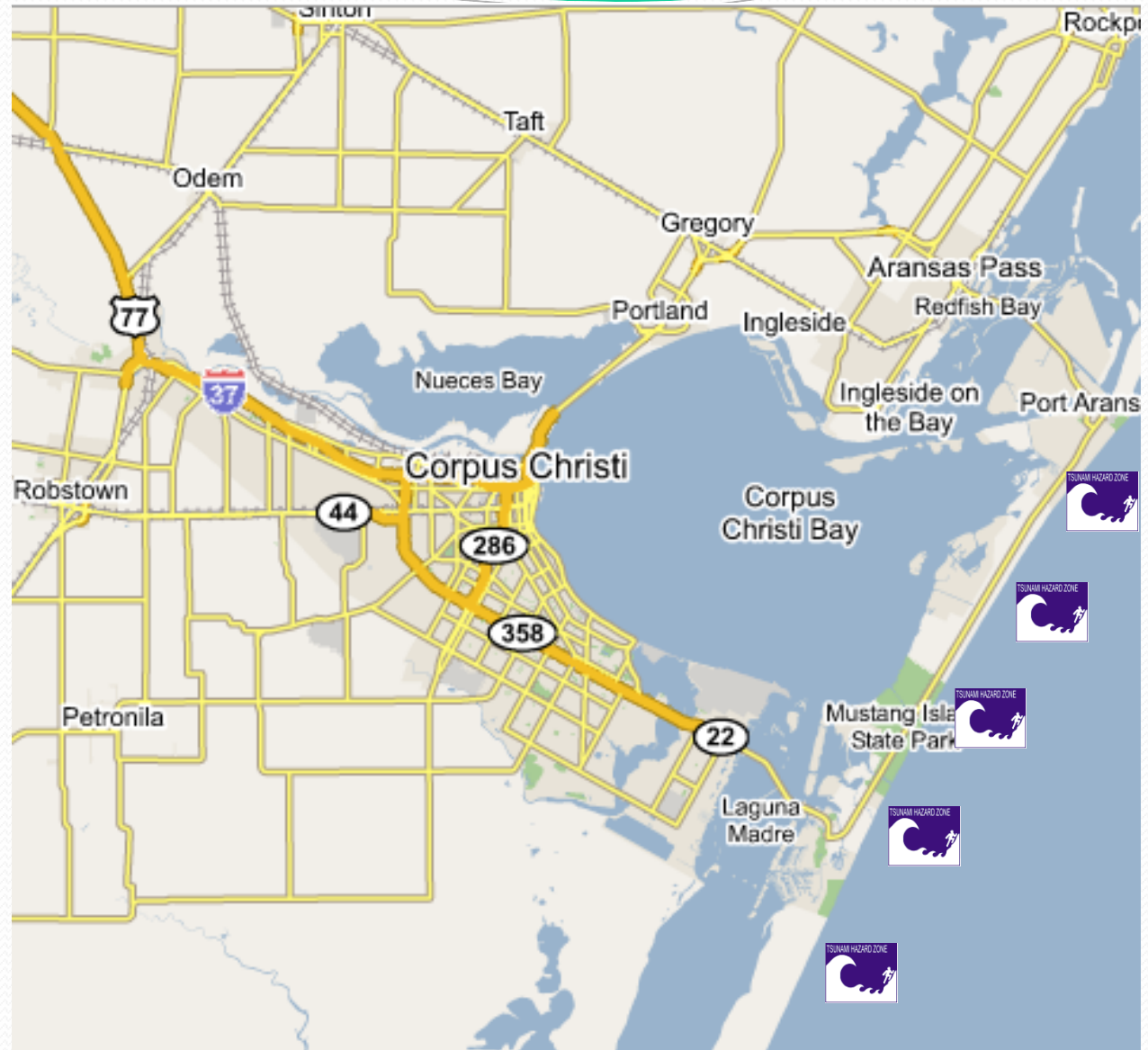
07.19.2005



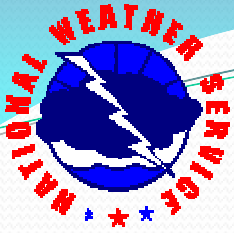




Tsunami Safe
Zone?



Education?



THE END

Special Thanks To:

National Geographic Channel

NOAA Tsunami Personnel

Various Tsunami Informational Websites